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FOREWORD

The basic MOSC Study encompassed a 9-month effort which examined the requirements for and established the definition of a cost-effective orbital facility concept capable of supporting extended manned operations in Earth orbit beyond those visualized for the 7- to 30-day Shuttle/Spacelab system. The study activity was organized into the following four tasks:

Task 1 Requirements Derivation

Task 2 Concepts Identification

Task 3 System Analysis and Definition

Task 4 Programmatics

In Task 1 the payload and mission requirements were examined for manned orbital systems with operational capabilities beyond those presently planned for the Shuttle/Spacelab program. These research activities were translated into characteristics of representative grouped payloads, including physical and operational parameters. The manned approach to research implementation was emphasized, as well as the lessons learned from previous Apollo and Skylab experience.

The second study task originally centered about the identification and definition of attached and free-flyer manned concepts to satisfy the requirements evolved from Task 1. Based upon the material presented in the first formal briefing, the study was redirected to conclude work on the attached mode of operation and concentrate the remaining effort on free-flying concepts.

Task 3 provided detailed definition of the baseline MOSC concept and the critical subsystem areas to a level required for subsequent programmatic analyses.

Task 4 developed project cost and schedule milestones related to the baseline concept in order to provide NASA with data useful for long-range planning activities and program analyses.

The study results are reported in four books. Book 1 presents an executive summary and overview of the study; Book 2 describes the derivation of requirements; Book 3 describes configuration development; and Book 4 describes the programmatic analyses.

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Section 1
INTRODUCTION

The next major step in this nation's manned space program will be a long-duration orbital facility which will extend the available manned mission stay time well beyond the 7- to 30-day periods currently projected for the Space Shuttle/Spacelab system. The Manned Orbital Systems Concepts (MOSC) Study has examined the requirements for extended missions and defined feasible approaches to achieving the goal of a permanent manned orbital facility with regular crew exchange, resupply of consumables, and a continuous scientific and applications program. This document describes the configuration concepts examined, the systems analyses conducted, and the subsystem definitions developed during the MOSC Study. The recommended orbital facility developed in the study is tentatively scheduled for an IOC in late 1984, thus the vehicle and subsystem concepts would follow chronologically the Space Shuttle/Spacelab, and can be expected to benefit from the proven hardware, technology, and operational experience of those programs. In conjunction with the Shuttle/Spacelab, MOSC should become an integral element as well as an essential building block in a new era of manned operational space activities.

The development of a rational and efficient approach to achieving extended-duration manned space flight must start with an understanding and identification of the spectrum of operational requirements that will be encountered. Once such factors as flight duration, orbital altitudes and inclinations, and general systems support are identified, it becomes possible to formulate conceptual approaches for the development of manned systems serving the needs of future missions. The initial study activity (MOSC Study Task 1) was directed toward identifying the operational requirements anticipated for the 1984-91 time period. Following the establishment of representative and reasonable requirements, key guidelines regarding configuration concepts

were considered; then the following basic questions were addressed:

1. Can the requirements of extended-duration manned missions be most effectively met by extending the basic Orbiter/Spacelab concept to longer missions (i.e., greater than 30 days)?
2. What are the minimum configuration requirements for an alternative manned orbital system to accomplish the operational objectives?
3. How effective is a given alternative orbital facility concept in accomplishing the identified program objectives?

Included in this book are the results of the trade studies and preliminary analyses conducted to answer the above questions for both the orbital vehicles and their subsystems. Major emphasis was placed on minimum cost, crew safety, vehicle conceptual design and design commonality, and growth flexibility for increased capability in advanced missions.

The technical investigations reported in this document were conducted under MOSC Study Tasks 2 and 3, which are summarized below.

Task 2 encompassed three steps: (1) identification of candidate concepts, (2) generation and analysis of detailed comparative tradeoff data, and (3) evaluation and selection of the concept which most effectively meets the MOSC requirements. This task originally centered about the identification and definition of both Shuttle-attached and free-flying concepts to satisfy the requirements evolved from Task 1, Payload Definition and Requirements. Based upon the analysis of the operational requirements defined in Task 1 and the limitations inherent in the attached-mode operation, the study team was directed early in the study to conclude work on the attached-mode operation and to concentrate the remaining effort on free-flying concepts. The extended-duration attached-mode concept trade study data which supported this decision are summarized in Appendix D.

Task 3 had the primary objective of providing detailed definition of the most effective concept identified in Task 2 that would be capable of supporting

the full spectrum of MOSC mission and payload requirements. This definition was to be carried to a level which would enable subsequent programmatic evaluation and thus included mission operations, subsystem characteristics, and interfaces among the elements of the MOSC and the Orbiter.

The remainder of this book describes the configuration analyses conducted during the study. In Section 2, the payload and program requirements which provided the starting point for the conceptual design are described. In Section 3, the important considerations driving the vehicle and subsystem configurations are discussed. Section 4 describes the free-flying concept development, and Section 5 describes the recommended baseline 4-man MOSC configuration and the associated subsystems. The salient points of the technical work accomplished in the preliminary definition of selected subsystems and vehicle concepts are presented in similar format for each subsystem area. In the subsystems section, for example, the following sequence is typically followed: (1) requirements, (2) candidate concepts, (3) recommendations, and (4) baseline subsystem descriptions.

Section 6 describes the operations analysis and Section 7 describes the evolutionary plan for future missions.

The appendixes provide supplemental detail on safety criteria and requirements (Appendix A), Space Shuttle payload accommodations (Appendix B), Skylab candidate hardware which could be utilized in advanced missions (Appendix C), a summary of the Shuttle-attached mode considerations (Appendix D), a limited-duration (three-man) concept (Appendix E), and a growth (six-man) concept (Appendix F).

Study results and recommendations must be evaluated and compared within the context of the fundamental guidelines and the major assumptions used in performing the analyses and/or developing the conceptual designs. Therefore, to provide such a frame of reference for the material to be discussed,

the original study guidelines are summarized as follows:

- Major emphasis will be placed on minimizing cost
- Emphasis will be placed on manned missions > 30 days
- Initial operational capability is to be late 1984
- All payloads will utilize Space Transportation System (STS) as the launch vehicle
- Available hardware and technology – Orbiter/Spacelab/Skylab – are to be utilized insofar as practical
- JSC 07700, Vol. XIV, Revision C and Spacelab Accommodations Handbook will be used as capability guides
- Weight constraints per flight are 65,000 pounds (29,484 kg) launch and 32,000 pounds (14,515 kg) planned landing
- Modules for resources and habitability will be considered
- Multiple flights and the Shuttle remote manipulator system (RMS) will be considered for assembly buildup
- Payloads and payload groups, as identified in the initial study task, are to be accommodated
- Payload (and/or module) accommodation will consider resupply of expendables, changeout at experiment level, on-orbit service, and changeout at MOSC module level (dedicated).

Of the preceding guidelines, minimum cost had the most direct influence inasmuch as it mandated the application of available hardware where feasible, e.g., Shuttle Orbiter communication subsystem major components, Solar Electric Propulsion Stage (SEPS) solar arrays, and the Apollo Soyuz Test Project (ASTP) international docking assembly. The development program cost evaluation substantiated the value of utilizing available hardware, particularly when the items are fully compatible with the MOSC-class mission and the Orbiter's environment.

Section 2
PAYLOAD AND PROGRAM REQUIREMENTS

The development of viable orbital facility concepts requires the coordinated accommodation of the operational requirements that "drive" the design. Those requirements having a direct effect on the MOSC class of orbital facility were divided into three primary categories: (1) payload and program requirements, (2) vehicle and subsystem configuration drivers, and (3) Space Shuttle payload accommodations and flight performance. Item 1 is discussed in this section and Items 2 and 3 are described in Section 3 and Appendix B, respectively.

The successful and efficient conduct of a payload program is directly dependent upon the level and flexibility of the subsystems support and vehicle accommodations; therefore, during the MOSC Study, payload and program requirements received full consideration in both definition of the vehicle concept and establishment of subsystems performance. The payload requirements were adjusted only to conform to established Shuttle discretionary payload capacity and cargo bay installation envelope.

The 19 reference MOSC payload combinations* which were used to provide the basic operational and design requirements for the remaining study tasks are listed in Table 2-1. Also shown are the major operational and physical characteristics/requirements for each payload described. The variance between the launch and landing payload weights is indicative of the expendables (cryogenics and fluids) utilized during the conduct of a flight or mission segment. The crew manhours listed represent a measure of the crew's relative involvement in activities necessary to perform the tasks required in the payload operation.

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*See Book 2, Requirements for Extended-Duration Missions, for further detail on these payloads.

Table 2-1

MOSC PAYLOAD COMBINATIONS

Payload	Description	Crew Manhours	Weight (1,000 lb) Up	Down	Volume (ft^3)	Avg Pwr (kW)	Miss. Dur (days)	Alt (nmi)	Orbit Inclin (°)
C1	IR Astronomy	1,454	31	25	4,500	1	80	216	28
C2	UV Astronomy	3,845	24	14	1,100	1	140	248	28
C3	Solar Observations	4,187	15	14	1,000	1	160	216	28
C4	Space Sciences 1	2,070	17	15	2,700	2	70	216	90
C5	Space Sciences 2	1,608	16	12	2,200	2	80	216	90
C6	AMPS/Earth Science	3,280	24	14	1,900	2	120	200	90
C7	Space Technology	884	26	17	2,300	10	40	200	28
C8	Cloud Physics/Technology	882	15	13	2,000	1	50	100	28
C9	Earth Science 1	851	25	24	6,100	2	50	200	90
C10	Earth Science 2	690	26	26	6,000	2	80	200	90
C11	High-Energy Astronomy/Technology	1,118	20	20	1,200	1	70	135	28
C12	Life Science/Technology 1	8,289	100	66	13,300	10	400	200	28
C13	Life Science/Technology 2	4,039	81	60	10,600	6	200	200	28
C14	IR/UV Astronomy	1,427	45	17	2,000	2	120	162	90
C15	UV Astronomy, Advanced	585	24	16	1,000	1	50	162	90
C16	Cosmic-Ray Lab	5,800	50	37	5,600	1	360	200	28
C17	LD Life Science Lab	23,200	39	34	2,600	8	720	200	28
C18	Advanced Technology	493	8	7	1,600	2	45	200	90
C19	Space Manufacturing	11,000	7	6	200	5	900	200	90

The prime consideration in grouping potential payloads into these 19 categories was the commonality of the scientific objectives and/or application areas to be considered in the conduct of the orbital activities. Compatibility between and among the various disciplines was assessed in terms of classes of activities and common functions (i. e., remote sensing, in-situ investigations, environmental perturbations, whole-body research, etc.). Mission requirements, desired orbital altitude and inclinations, common environmental requirements, and similar crew assignments and functions were also considered. In addition to equipment and operational factors, crew skills were evaluated in the groupings insofar as a reasonable cross-training among the crew members for payload operations and servicing appeared feasibile.

In several cases, where one or two payloads exhibited a requirement that extended slightly beyond the normal band, deviations were accepted. This approach was taken in order to avoid excess capacity, development of a new or larger component, etc. A case in point is the electrical power to be supplied to the payloads.

The summary table indicates that power levels of approximately 6 kW satisfy all but three payload groupings which require 8. 0 to 10. 0 kW. The SEPS foldout solar array, which is currently under development, will supply sufficient power for the subsystems (approximately 4. 2 kW) and most of the payloads. At the beginning of solar array life, the power available to payloads is approximately 8. 5 kW. If a minimum 5-year degradation of 10 percent is assumed, the payload power would be reduced to approximately 7. 5 kW. However, during the first 2-1/2 years adequate power would be available, and during the last 2-1/2 years the power system comes very close to supplying the C-17 (Long-Duration Life Science Laboratory) 8. 0-kW payload demand. Under the most severe degradation assumed – 25 percent in 5 years – approximately 5. 5 kW would be available at the end of the period. For this condition, the 10. 0-kW payloads – C-7 (Space Technology) and C-12 (Life Science Technology No. 1) – would require adjustments in subsystem and payload power use scheduling or, if necessary, a supplemental power source would be provided.

The evaluation of the payloads which prefer missions of longer duration, as described in Book 2 of this report, established the following general design criteria:

- Flight Duration: Support 720-day missions
- Crew Size: Up to four specialists per payload group
- Crew Rotation: 90-day nominal; 180-day maximum unless additional time is required for biomedical research subjects
- Payload Power: 8.5 kW (supplemental to 10.0 kW)
- Orbit Altitude: 200/230 nmi nominal
- Orbit Inclination: 28.5° /90°
- Altitude Change Capability: ±95 nmi (28.5° - subsynchronous and low-altitude payloads)
- Platform Orientation: All attitudes, vehicle pointing to 0.1° accuracy
- Onboard Disturbance Levels: $<10^{-5}$ g

  Contamination: Equivalent to 100,000-class clean room (pressurized module)
- Data Management: Real-time 5 MHz; recover hard copy, film, tapes, materials; closed-circuit TV
- Communications: Real-time to payload control centers
- Accommodation Features:

  Two-man EVA on routine basis

  Scientific/equipment airlock

  Payload equipment fully accessible

  Modularized payload carriers
- Operational Features:

  Dual crew escape routes from all modules

  Exchange payload specialists

  Multiple/simultaneous active payloads

  Return all or part of payload equipment

  Resupply payloads

  Double-ended, universal docking provisions

The following general program requirements which had a direct effect upon the design criteria were established as study guidelines:

- Economy: Effective utilization of existing hardware and technology
- Schedule: IOC late 1984 at 28.5° orbital inclination, 1986 at 90.0°.
- Design Flexibility: Provide for evolutionary growth
- Reliability: Nominal 5-year system orbital operations life
- User community: International utility, scientific, technological applications, industrial/commercial operations, space systems servicing and support
- Weight estimates: Include 10 percent contingency on new hardware.

The application of the design criteria and program guidelines to this study determined that the STS can adequately support the Space Station mission, and both orbital vehicle and subsystems can be configured from existing hardware or technology to successfully accommodate a major payload program.

Section 3

VEHICLE AND SUBSYSTEM CONFIGURATION DRIVERS

The significant factors which were considered and collectively applied in the configuration selection and the conceptual designs are the following:

- Payload support requirements (discussed below)
- Application of available hardware/technology (see Section 4)
- Habitability requirements (see Section 5)
- Crew safety requirements (discussed below)
- Shuttle Orbiter performance and characteristics (see Appendix B)
- Mission/orbital parameters (see Section 2)

Of these factors, crew safety was considered to be of paramount importance in the conceptual design process. It was found that the application of crew safety requirements had more influence on the vehicle configuration definition than in subsystem selection and design. Generally, the subsystems could be modified or an operational or performance feature added which fulfilled the safety requirement. Complete documentation of the design and operations safety criteria and requirements which were utilized in the study may be found in Appendix A. The key safety items are summarized as follows:

- No single malfunction will result in loss of personnel or vehicle
- Subsystems must fail-operational to continue mission and fail-safe to permit rescue
- EVA equipment and emergency support will be available under a single catastrophic condition – 4 days* of emergency life support/consumables will be provided
- One docking port with a two-man airlock or equivalent will be available for emergency rescue under single-catastrope conditions

*The original study guidelines indicated that the emergency Shuttle turnaround time would be 4 days (96 hours) and this figure was used in the MOSC Study for sizing emergency support provisions. More recent data have suggested that 160 hours might be a more realistic estimate. Future provisioning studies should base emergency supplies on a 160-hour requirement.

- Modules will be isolatable for hazard control and rescue
- ECLS subsystem will have sufficient capacity to repressurize any one module
- Secondary structure and internal equipment will provide access for damage control and repair
- High-pressure bottles/tanks will be located outside of and as remote as possible from crew working/living areas
- Docking hatches will provide a clear opening at least 1m in diameter
- Shirtsleeve inspection, maintenance, and repair of docking assembly mechanisms will be provided.

A major safety-related influence on the vehicle configuration was the requirement for individual modules which can be isolated and provide crew life support during the mounting of the rescue mission. For initial sizing, the Shuttle baseline of a 4-day turnaround and launch capability was applied to establish the basic support period to be provided. In addition, under most emergency conditions residual consumables would be available to extend the basic period, if required. However, should Shuttle turnaround times be extended, the emergency supplies should be adjusted accordingly. An additional element in this consideration is the requirement for a Shuttle docking capability under single-catastrophy conditions. This demands that a docking port be installed at both outboard ends of the assembled vehicle, regardless of the number of modules.

Although the key safety criteria were compiled within all areas of the basic vehicle design, the international docking assembly (IDA), which is the basis for both the modular assembly and Shuttle docking, does not fully conform to the applicable criteria. It does not meet the requirement for a 1-m clear opening, as its present opening is approximately 31.5 inches (80 cm). This may be marginally acceptable for long-duration activity; however, a detailed evaluation must be conducted to obtain qualifying data. In addition, the IDA cannot be maintained under "shirtsleeve" conditions in a pressurized area. This feature is important for core vehicle modules which would be scheduled to remain in orbit for up to 5 years.

Payload support requirements, mission orbital parameters, and Shuttle Orbiter performance were primary in the selection of subsystem technology, e.g., open- versus closed-system approach, level of performance, and sizing. In close relationship with these factors was the availability of current hardware or technology, which was a prime factor when related to program cost comparison and confidence in selected subsystem performance.

To control cost and to ensure that performance requirements were met in the development of the MOSC vehicle configurations, the study team utilized Orbiter/Spacelab technology where feasible. The resulting MOSC vehicle configurations are based on variations of the basic modular elements and have the capability necessary to support the identified payload program. The mission guidelines and operational characteristics which were derived from the payload requirements analyses (Book 2) are summarized in Table 3-1.

3.1 ROLE OF MAN IN LONG-DURATION ORBITAL OPERATIONS

The Task 1 analysis clearly indicated that the two most important roles of the crew in orbital operations were maintenance and operations control. In the crew assignments for the 19 combination payloads selected, 23 of the 60 crew positions could be filled by crewmen with electromechanical maintenance and servicing skills. With regard to man's role in the control and operation of the orbital equipment, the crewman's presence and his overview and direction of orbital scientific and applications activities improves the quality of the activities and/or increases the knowledge gained. Two other functions of the crewmen in the MOSC would be the performance of IVA transfer and resupply operations and the performance of EVA operations, both in scheduled timelines and in unscheduled maintenance/repair activities.

3.1.1 Orbital Maintenance

Between one-third and one-half of all the tasks assigned to the crew on the 19 combination payloads of Task 1 involve maintenance, servicing, and calibration of the orbital equipment. By using the capabilities of the crew, the equipment can be basic in design, less complicated, and lighter in weight than equivalent unmanned-automated operations. In summation, the role of man in maintenance operations has a two-fold purpose: (1) to allow lighter,

Table 3-1

MISSION GUIDELINES AND OPERATIONAL CHARACTERISTICS

I. MISSION/VEHICLE DESCRIPTION	
• Vehicle Orbital Life	5 years or more
• Resupply Period	60 to 90 days
• Crew Size	3 to 6
• Power Level	
- Total	25.0 kW
- Bus	12.5 kW at beginning of life
• Number of Modules	2 to 4
• Pressurized Volume	Short module
	Long module
• Number of Pallets	1 to 3
• Orbital Altitude	200 nmi nominal
• Orbital Inclination	28.5°/ 90°
• Vehicle Orientation	All axes
• Docking Mechanism	ASTP international docking assembly
II. OPERATIONAL CHARACTERISTICS	
• Cabin Atmosphere	
Composition	(Air)
Pressure	1 atm
Humidity	43°F (6°C) DP to 60% RH
Temperature	65 to 80°F (18 to 27°C)
CO_2 Level	5.0 mm Hg maximum
III. EXPERIMENT REQUIREM	
• Pressurized Equipm	
Pressure	1 atm
Humidity	60% maximum
Operating Temp	
(typical range	Upper end 70° to 140°F, 294 to 313 K
	Lower end 32° to 72°F, 273 to 295 K
• Unpressurized - pa nted[1]	
Operating Ter es	
(typical rang	-280° to 203°F, 100 to 368 K
• Number of EVAs	1 every 20 days - 2 crewmen[2]
• Scientific Airlock Repressurizations	1 every 7 days (ST-21-S only)[3]

[1] Pallet-mounted equipment es further installation design and analyses to define the passive- vers ve-cooling requirements.

[2] A preliminary survey of th riments that require EVA, e.g., EO-05-S Shuttle Imaging Microwave System enna deployment, CN-085 Open Traveling-Wave Tube - boom deployment, and phot pment that will require film retrieval and reloading, determined that one EVA pe ry 20 days would meet the requirements.

[3] Deployment of photometer a V camera for barium cloud studies.

simpler equipment designed for performance of maintenance and servicing operations and (2) to raise the probability of mission success through crew-performed maintenance and service operations. However, it should be noted that crew overuse for maintenance operations at the continuing expense of control functions and/or research-related duties must be avoided. It will be necessary during real-time mission planning to continually optimize man's role as the particular mission goals change.

3.1.2 Control of Operations

As noted above, the control of orbital operations is one of the more important crew responsibilities. In controlling operations, the crew members have two primary roles: (1) to direct overall operation of experiments and (2) to improve the quality of the data obtained and returned. In such areas as space processing, life sciences, and space technology, the Skylab crew would often control or modify the experimental activities based on what was occurring in the experiments. In the areas of observation, such as astronomy, high-energy physics, meteorological research, and Earth observations, the crew would direct the observations to improve the quality and quantity of the experimental data. During the Skylab missions, for example, the ATM console operator, by observing and selecting what was to be recorded, enhanced the data return. In another case, during the third Skylab mission, the crew was able to utilize a solar and Earth observation facility by reorienting the vehicle and going EVA to observe the comet Kohoutek. If the Skylab program had instead been two separate unmanned programs, one for solar observation and one for Earth observation, it is unlikely that either would have been capable of modifying its operational performance to observe the comet.

3.1.3 IVA Operations

Intervehicular and intramodular consumables transfer and resupply operations is an area where man's capability can be augmented through weightlessness in space. The Skylab crew repeatedly moved items with large mass (over 250 pounds) with much less effort and fewer control problems than had been anticipated. The MOSC vehicle configuration made use of Skylab experience in utilizing man to facilitate regularly scheduled transfer and resupply operations.

3.1.4 EVA Operations

Extravehicular operations have been and will continue to be costly in terms of crew time and consumables required and, therefore, the requirement for EVA operations should be carefully reviewed and optimized. However, in both normal service (e.g., film retrieval and reloading of cameras) and unscheduled repair, the crew has proved to be indispensable by performing EVA operations. Where experiment equipment requires remote deployment or service functions, EVA may be the most economical approach. In the case of Skylab, EVA operations proved critical to mission success.

3.1.5 Design Implications

The following design guidelines for the MOSC hardware and operations have been drawn from manned flight experience to date. The guidelines are not intended as all-inclusive, but they do highlight some of the more important observations from programs such as Skylab.

- In designing for maintenance, the handling of many small, loose pieces should be minimized.
- In operations control, the crew member should be assigned the tasks that make use of his overview in decision-making and leave the simple repetitive tasks to the automated equipment.
- To expedite resupply operations, the mass of supplies to be moved should be as large as possible within the size limitations of the on-orbit transfer path.
- EVA accommodations should allow for access to the entire exterior of the vehicle.

3.2 SPACE SHUTTLE PAYLOAD ACCOMMODATIONS

The Shuttle Orbiter performance and payload bay accommodations directly affect the configuration definition and interface considerations of the MOSC. These Shuttle Orbiter characteristics are shown in Table 3-2, together with the spacecraft characteristics and subsystem affected. The major items are identified in the table. A primary and secondary study application indicator is included in the table to show those primary characteristics considered during analytical evaluation in this initial study and those that must be applied to detail preliminary design in a subsequent study phase. For

Table 3-2

SHUTTLE ORBITER INTERFACE AND PERFORMANCE CHARACTERISTICS VERSUS MOSC REQUIREMENTS

Space Shuttle Operation Elements	Space Shuttle Characteristics	MOSC Study Application Primary	MOSC Study Application Secondary	MOSC Spacecraft, Subsystem, or Operational Effect
1. Shuttle Orbiter Cargo Bay	1.1 Installation clearance envelope 15-foot diameter x 60 feet long, less 7.5 feet for docking module, leaves 52.5 feet clear installation length. (Ref. Docking Module, Para. 1.4)	X		1.1 Controls the total length of modules assembled for a single launch and the arrangement and length of specific modules and pallets.
	1.2 Payload installation structural support and mounting details		X	1.2 Preliminary basis for spacecraft mounting is equivalent to the Spacelab mounting system based on structurally determinant support. Sufficient flexibility exists in the mounting provisions to meet the various module arrangements.
	1.3 Center of gravity envelope	X		1.3 Module and function relationships were arranged to meet the specified criteria within a ±20 percent tolerance on weights. Location of major components or consumables will ensure proper location of center of gravity.
	1.4 Docking module envelope and function	X		Primary method for attaching a MOSC module in orbit supporting initial orbital checkout, crew transfer, and rescue.
2. Prelaunch Operations	2.1 Horizontal access in Orbiter processing facility — MOSC installed in Orbiter cargo bay (Ref. Para. 1.4)		X	2.1 Same basic access as Spacelab — through airlock and docking module.
	2.2 Vertical access on launch pad		X	(TBD)
3.0 Launch and Landing Loads	3.1 Launch loads		X	3.1 MOSC is not limited by the 65K launch capability
	3.2 Landing loads	X		3.2 MOSC core vehicle gross weights including ≈15 days of consumables are within ±10 percent of the 32K pound for the heaviest modular assembly, which meets the planned Shuttle Orbiter landing load requirement; however, MOSC core vehicle modules are not intended to be returned in other than an emergency situation.
4.0 Orbital Mission Operations	4.1 MOSC deployment with the remote manipulator system	X		4.1 Deployment from Shuttle Orbiter bay is with the remote manipulator system, which docks the MOSC to the docking module.
	4.2 Final subsystem checkout and crew transfer		X	4.2 Docking interface on docking module would provide checkout control and data transmission and allow IVA crew transfer.
	4.3 Orbital rendezvous and docking	X		4.3 Shuttle docking dynamics were used in sizing MOSC propulsion subsystem. Shuttle RCS payload contamination potential identified during study
	4.4 Shuttle performance	X		4.4 Shuttle payload capability versus altitude determined maximum operational altitude
	4.5 Single remote manipulator system	X		4.5 Necessitates utilization of Orbiter docking module for most orbital assembly/disassembly operations.

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convenient reference, a summary of the pertinent requirements from JSC 07700, Space Shuttle System Payload Accommodations Report, which were applied in developing the preliminary MOSC configurations, is provided in Appendix B.

3.3 PAYLOAD ENVIRONMENTAL PROTECTION

The Shuttle interface impacts upon representative payload class and configuration concepts were investigated for active thermal control, cleanliness criteria, EMC tolerances, acceleration levels, and radiation protection. Table 3-3 lists the key requirements for environmental protection of payloads and MOSC elements launched by the Shuttle. The MOSC module and payload data were derived by the study team specialists and or from documentation from previous programs.

The only significant radiation source apart from the naturai phenomena (radiation belts or solar flares) defined in this and previous studies is the possibility of a nuclear power source. If this candidate power subsystem is selected, it could have significant impact on the Orbiter; however, the shielding required would be payload-provided and payload-weight chargeable. Small radioisotopes will be used in some life science payloads, but their radiation levels would be at a low level, precluding a significant shielding requirement. Many of the experiments are sensitive to radiation, expecially the UV and IR telescopes and the communication/navigation experiments. However, the exposure levels inside the Orbiter bay will normally not exceed the allowable levels for these experiments. A possible exception can occur during solar flares when limits could be exceeded. Some types of highly sensitive film could be affected by radiation; however, this requirement will not have an impact on Orbiter design. If a film vault is chosen to protect the film, the vault will be mounted in the MOSC. The advisability of including a film vault will require additional evaluation. Skylab experience demonstrated that film vaults were not fully effective because of secondary radiation caused by high-energy-particle impacts in the shield material. However, the quality of photographs was good because of special techniques and image enhancement procedures.

Table 3-3 (Page 1 of 2)

PAYLOAD ENVIRONMENTAL INTERFACE CHARACTERISTICS

MOSC Payload Combination		Source	Radiation Sensitivity	Thermal Control Launch	Thermal Control Entry	Electromagnetic Compatibility Conducted db μv	Electromagnetic Compatibility Radiated db W/M^2	Maximum Acceleration g	Particle Contamination Cleanliness[1]
C-1 IR Astronomy	Press.	None	2.78 E-9 J/kg-s[4] 7.2 E-5 J/kg[3]	Inactive	Inactive	0.1 TBD	90 -90	5	100 K
	Unpress.	None	2.78 E-9 J/kg-s 7.2 E-3 J/kg	Inactive	Inactive	0.1 TBD	90- -90	5	1 K
C-2 UV Astronomy	Press.	None	2.78 E-11 J/kg-s 1.7 E-5 J/kg	Inactive	Inactive	TBD	-120	5	100 K
	Unpress.	None	2.78 E-11 J/kg-s 7.2 E-5 J/kg	Inactive	Inactive	TBD	-90	5	1 K
C-3 Solar Observation	Press.	None	Insensitive (1) 1000 J/kg	Inactive	Inactive	30	140 at 30 Hz; 20 at 3E + 04 Hz	5[2]	100 K
	Unpress.	None	1.5 E-6 J/kg-s 0.019 J/kg	Inactive	Inactive	30	140	5[2]	5 K
C-4 Space Science #1	Press.	None	4.1 E-8 J/kg-s 0.02 J/kg	Inactive	Inactive	0	0	4	100 K
	Unpress.	None	1.4 E-10 J/kg-s 1.1 E-4 J/kg	Inactive	Inactive	60	20 at 30,000 Hz	4	50 K
C-5 Space Science #2	Press.	None	1.7 E-8 J/kg-s 0.01 J/kg-s	Inactive	Inactive	Ref. Mil Standard 461A		3.5	100 K
	Unpress.	None	1.4 E-10 J/kg-s 1.1 E-4 J/kg	Inactive	Inactive	Ref. Mil Standard 461A		3.5	50 K
C-6 AMPS Earth Science	Press.	None	4.1 E-8 J/kg 0.02 J/kg	Inactive	Inactive	0	0	3.5	100 K
	Unpress.	None	1.4 E-10 J/kg-s 1.1 E-4 J/kg	Inactive	Inactive	60	20 at 30,000 Hz	3.5	50 K
C-7 Space Technology	Press.	None	Manned Level Acceptable	Inactive	Inactive	TBD	TBD	4	100 K
	Unpress.	None	Manned Level Acceptable	Inactive	Inactive	TBD	TBD	4	100 K[1]
C-8 Zero G Cloud Physics Technology	Press.	None	1.7 E-4 J/kg-s 3.0 J/kg (TBD)	Inactive	Inactive	MIL-STD 491A MIL-STD 461	MIL-STD 491A MIL-STD 461	5	20 K
	Unpress.	None	Manned Level Acceptable	Inactive	Inactive	MIL-STD-461	MIL-STD-461	5	100 K[2]
C-9 Earth Science #1	Press.	None	8.3 E-6 J/kg-s 5.0 J/kg	Inactive	Inactive	MIL-STD-461A	MIL-STD-461A	3.5	100 K
	Unpress.	None	8.3 E-6 J/kg-s 5.0 J/kg	Inactive	Inactive	MIL-STD-461A	MIL-STD-461A	3.5	100 K
C-10 Earth Science #2	Press.	None	8.3 E-5 J/kg-s 5.0 J/kg	Inactive	Inactive	MIL-STD-461A	MIL-STD-461A	3.5	10 K
	Unpress.		8.3 E-6 J/kg-s 5.0 J/kg	Inactive	Inactive	MIL-STD-461A	MIL-STD-461A	3.5	10 K
C-11 High Energy Astro. 1 Technology	Press.	None	No	Inactive	Inactive	TBD	TBD	5	100 K
	Unpress.	None	No	Inactive	Inactive	TBD	TBD	5	1 K

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Table 3-3 (Page 2 of 2)

PAYLOAD ENVIRONMENTAL INTERFACE CHARACTERISTICS

MOSC Payload Combination		Radiation Source	Radiation Sensitivity	Thermal Control Launch	Thermal Control Entry	Electromagnetic Compatibility Conducted db μv	Electromagnetic Compatibility Radiated db W/M²	Maximum Acceleration g	Particle Contamination Cleanliness(1)
C-12 Life Science/Mate. Tech. #1	Press.	Radio-isotopes Small	Manned Level	Active	Active	Manned Level Acceptable	Manned Level Acceptable	3.3	100 K
	Unpress.	None	Insensitive	Inactive	Inactive	Manned Level Acceptable	Manned Level Acceptable	3.3	N/A
C-13 Life Science/Mate. Tech. #2	Press.	Radio-isotopes Small	Manned Level	Active	Active	Manned Level Acceptable	Manned Level Acceptable	3.3	100 K
	Unpress.	None	Insensitive	Inactive	Inactive	Elements of this payload pose potential source of EMI	Elements of this payload pose potential source of EMI	3.3	100K
C-14 IR/UV Astronomy	Press.	None	2.78 E-11 J/kg-s/TBD 7.2 E-5 J/kg-TBD	Inactive	Inactive	TBD	-120 db W/M²	5	100 K
	Unclass.	None							
C-15 UV Astronomy	Press.	None	2.78 E-11 J/kg-s/TBD 7.2 E-5 J/kg-TBD	Inactive	Inactive	TBD	-120 db W/M² (TBD)	5	100 K
	Unpress.								
C-16 Cosmic Ray Laboratory	Press.	None	Emulsion Constraints	Inactive	Inactive			5	100 K
	Unpress.								
C-17 Long Duration Life Science Laboratory	Press.	Radio-isotopes Small	Manned Level	Active	Active	Manned Level Acceptable	Manned Level Acceptable	3.3	100 K
	Unpress.	Radio-isotopes Small	Manned Level	Active	Active	Manned Level Acceptable	Manned Level Acceptable	3.3	100 K
C-18 Adv Technology	Press.	None	8.3 E-6 J/kg-s 5 J/kg (1)	Inactive	Inactive	MIL-STD-461	MIL-STD-461	5	100 K
	Unpress.	None	8.3 E-6 J/kg-s 5 J/kg (1)	Inactive	Inactive	MIL-STD-461	MIL-STD-461	5	100 K
C-19 Space Manufacturing	Press.	None	Manned Level			Manned Level (TBD)	Manned Level (TBD)	4	100 K
	Unpress.	None	Manned Level			Potential Source of EMI (TBD)	Potential Source of EMI (TBD)	4	100 K
Habitability Module		None	Film	Yes if Life Sciences		Yes if Life Sciences		Design to 4	100 K
Subsystem Module		Possible if nuclear power	No	Possible if nuclear power		None	No	Design to 4	100 K
Logistics Module		None	Film	None	No	None	No	Design to 4	100 K
Payload Module		None	No	None	No	None	No	Design to 4	100*K

(1) Air Cleanliness class per Federal Standard 209B (2) Data extrapolated from similar payloads (3) Unit radiation rate (4) Unit dose

Life science laboratories require two types of active thermal cooling from the MOSC/Orbiter. The first is coldplate cooling for the electronic components and certain experiment equipment items. The second is the cabin cooling required because of the metabolic heat due to live specimens. The cabin cooling requirements may cause problems, particularly during the launch or recovery of the payload.

To ensure that payload equipment will meet electromagnetic compatibility requirements and be in compliance with the Shuttle and MOSC, it should be designed to MIL SPEC 461A. Sensitive equipment could provide its own protection if the sensitivity requirement is greater than that required by the MIL SPEC. Since the Orbiter also complies with this specification, no incompatibilities are expected.

The acceleration levels listed in Table 3-3 range from 3.3 to 5 g's. These values are compatible with the levels currently anticipated for all Orbiter mission conditions except for crash landing. This condition of up to 9 g's in the longitudinal direction exceeds the allowable levels for all payloads. The crash landing condition, a containment requirement, i.e., the equipment can fail but not cause damage to other payload or Orbiter equipment. Therefore, the 9-g condition is not considered an operational incompatibility; however, each payload must meet the crash-landing limit as well as the steady-state limit. Each detailed analysis of the final design can ascertain if the steady-state or crash-landing limits are controlling.

The Orbiter cargo bay provides the following cleanliness levels during payload loading and checkout. Prior to payload loading the internal surfaces of the cargo bay envelope will be cleaned to a visibly clean level, as defined in JSC specification SN-C-0005. This cleaning will be accomplished using a protective enclosure to isolate sources of contamination from critical regions. This enclosure will be continuously purged with nominally Class 100, guaranteed Class 5000 (HEPA filtered) air per FED-STD-209B and will contain fewer than 15 parts per million hydrocarbons, based on methane equivalent. The air within the enclosure will be maintained at 70 ±5°F and 45 ±5 percent

relative humidity. The payload loading operation will be accomplished in such a manner as to avoid contaminating the payload and cargo bay by temperature, humidity, and particulates, consistent with other sections of these requirements. More stringent particulate and relative humidity requirements may be implemented on particular payloads pending technical justification of the requirements.

Section 4
CONCEPT DEVELOPMENT

The primary objectives of the vehicle configuration concept selection (Figure 4-1) effort was to: (1) conceive and evaluate potential configurations which are responsive to the mission, experiment, and design requirements identified in earlier portions of the study, and (2) to recommend one or more conceptual approaches for analysis to a level required for programmatic cost and schedule estimates. The key issues include: (1) providing a viable concept meeting the requirements for crew sizes of 4 to 6, long-duration (>30 days), and responsiveness to a wide range of payloads (19 combinations for this analysis), (2) utilizing man to enhance the approach, (3) considering a balanced application of hardware developed during the Shuttle/Spacelab era versus new systems or technology, and (4) providing concepts which enhance future applications or growth versions.

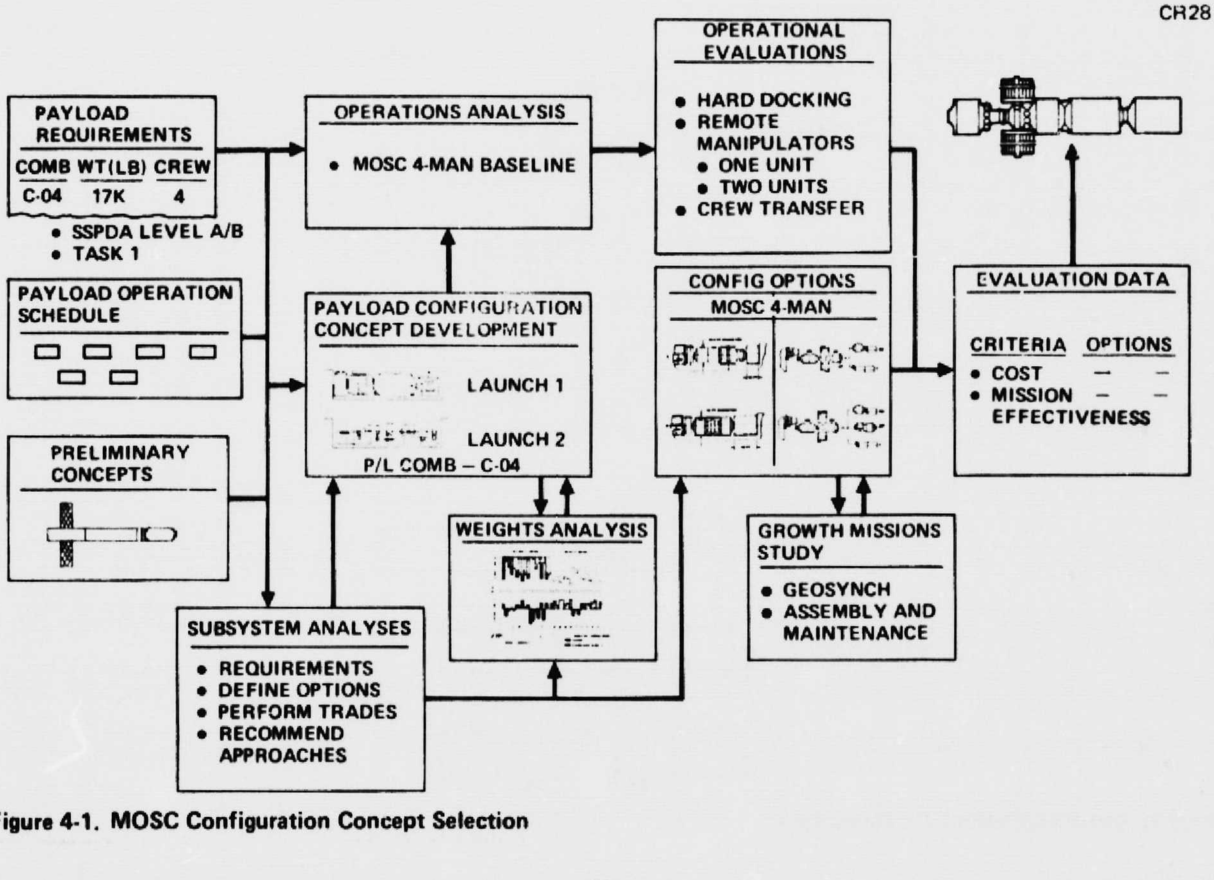

Figure 4-1. MOSC Configuration Concept Selection

To consider these issues and develop a conceptual space station design within that framework, the following three primary tasks were undertaken: (1) concept options were identified and compared, (2) detailed subsystem comparative tradeoff data were generated and analyzed (see Section 5), and (3) the vehicle concepts most effectively meeting the MOSC study and design criteria were identified and evaluated, and a baseline concept was selected.

In the study, both Shuttle-attached (extended Orbiter/Spacelab) and free-flying concepts were considered initially in an attempt to satisfy the payload requirements for extended-duration missions.

In approaching the question as to the feasibility of extending the basic Orbiter/Spacelab concept to orbital periods greater than 30 days, it must be recognized that Spacelab is not a single-vehicle configuration. The Spacelab concept consists of several modules that may be assembled in different combinations to accommodate specific payloads. Spacelab has four baseline configurations combining long and short modules and pallet segments as shown in Figure 4-2. Other combinations are also described in the Spacelab accommodations hand-

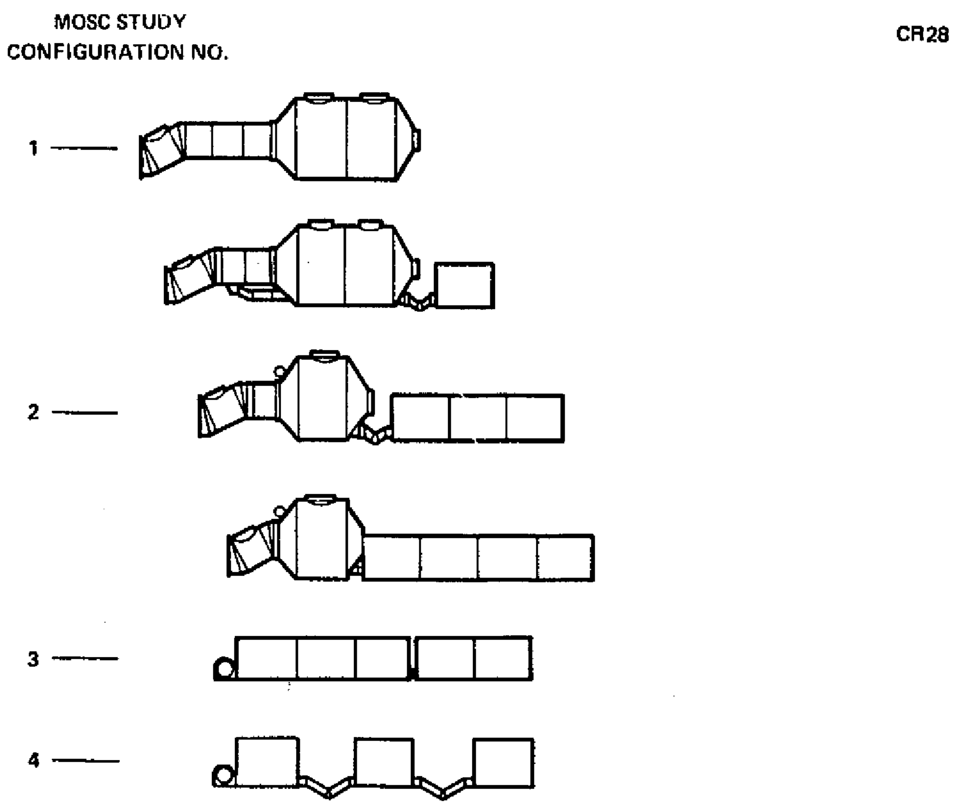

Figure 4-2. Spacelab Baseline Configurations

book. The initial evaluation step was to examine the basic Orbiter/Spacelab capabilities and to determine whether special kits or multiple launches could be used to meet the requirements for extended-duration missions.

It was concluded that for extended-duration missions (those beyond 30 days), the down payload weight (landing) limitation of the Orbiter would necessitate leaving portions of the total system in orbit. Thus since a free-flying station-keeping capability would appear to be required in either the Shuttle-attached or free-flying modes of operation, the study team was directed by NASA to concentrate the study effort on the free-flying mode of operation. The trade-off analysis supporting this conclusion is presented in Appendix D.

4.1 CONFIGURATION CONCEPTS

A wide range of potential free-flying concepts would conceivably satisfy the mission-payload needs as established in Task 1. In this initial evaluation, it was necessary to identify basic mission concepts from which the selected approaches could establish the baseline mission for vehicle and subsystem configuration evaluation and selection. A matrix of possible concepts was prepared for the free-flying mode of operations. This matrix served to initially identify the concepts and was arranged to include the variations in the functional requirements which are the major configuration drivers. These basic influence factors have been established and confirmed by previous manned space station studies and manned space flight experience. There are other requirements (e.g., individual payload characteristics) which also influence the configuration; however, the following factors ultimately have the most significant effect on the general configuration and operational capabilities of the concept: (1) mission duration, (2) crew size, (3) electrical system power source, (4) mission mode, and (5) launch mode, e.g., a single launch and/or multiple launches. Application of these key drivers to each set of functional requirements resulted in a set of concepts that was then reviewed against the payload and mission requirements to finalize and select the most effective concepts for more detailed analyses and vehicle configuration definition. Figure 4-3 is the decision tree used to formulate preliminary concepts for achieving mission objectives based on the key requirements for the free-flyer.

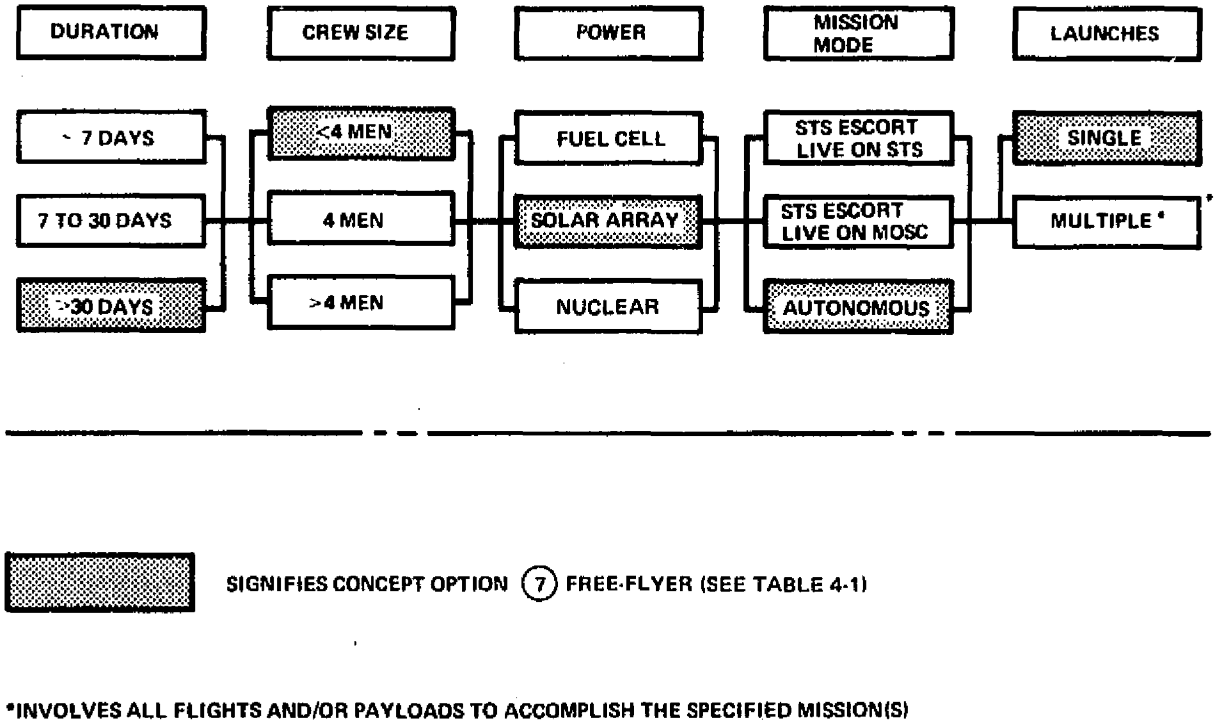

Figure 4-3. Mission Concept Decision Tree — Free-Flying MOSC Primary Influence Factors

The present Orbiter and Spacelab are being designed for 7-day missions with potential to extend to 30 days; consequently only missions of greater than 30 days duration were considered for the free-flyer. Skylab experience regarding crew accomplishments and Task 1 results indicates that within the payload weight and volume limitation for a single Shuttle launch, three or four experimenters would be appropriate for short missions and four or more for long missions, due to the greater number of experiments. Preliminary analyses of free-flyers indicate that fuel cell and/or solar array systems can best support the defined missions. The missions and operational concepts do not require advanced technology (i.e., nuclear, etc.) power supplies. In this evaluation, the mission mode becomes very significant as a prime orbital vehicle concept driver. The mission mode essentially indicates the role of man in the operation. The permanently manned MOSC and autonomous orbital operations represent this major mode. In this case, the crew would operate the MOSC after the Orbiter has de-orbited, and would be returned to Earth via a later Orbiter flight. Twelve optional concepts were selected for further analyses based on elimination of the short-duration missions, more than four crewmen, "other" power sources, and the

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STS mode of operation. The concept's growth potential to accommodate larger crews was included in the configuration definition. These 12 options, of which six involve multiple-launch considerations, are listed in Table 4-1. Based on an analysis of the potential power sources for extended missions (see Section 3.3.2), the solar array systems are the minimum weight systems for durations beyond 15 days. Therefore, only solar array systems were considered in subsequent analyses. On this basis, there are

Table 4-1

CONCEPT OPTIONS SYNTHESIS – FREE-FLYING

	Primary Influence Factors									
	Duration	Crew Size			Power		Mission Mode		Launches	
Concept Option	>30 Days	<4 Men	4 Men	>4 Men	Fuel Cell	Solar Array	MOSC	Autonomous	Single	Multiple*
1	X			X	X		X		X	
2	X			X	X		X			X
3	X			X		X	X		X	
4	X			X		X	X			X
5	X	X			X		X		X	
6	X	X			X		X			X
7	X	X				X	X		X	
8	X	X				X	X			X
9	X		X		X		X		X	
10	X		X		X		X			X
11	X		X			X	X		X	
12	X		X			X	X			X

*Involves all flights and/or payloads required to accomplish the specified missions.

six options remaining; three single and three multiple-launch cases. These six concepts were considered in the detailed analysis of the requirements.

The application of data from past trade studies of both manned and automated payloads and experience from Skylab, Spacelab, and the Phase-B Modular Space Station studies have been used to rationally reduce the total number of requirements sets to a manageable number of logical concepts.

The initial evaluation determined that the Option 11 (Table 4-1) concept would be most effective in meeting the MOSC guidelines in supporting the Task 2 experiment plan. However, the subsequent detailed analysis that included vehicle and payload weights and preliminary configurations determined that two Shuttle launches would be necessary. Therefore, the Option 12 concept became the baseline.

Using existing studies and hardware programs such as Spacelab, Skylab, and the NASA Phase-B Modular Space Station, weights were parameterized for crew size, mission duration, power level, etc., as appropriate.

Using vehicle length and volume as the primary consideration, the payloads, equipment, and support elements were configured. These configurations in turn were referenced to the Task 1 preliminary payload analysis for assessments of payload weights and support elements. Each payload combination was evaluated against the Orbiter cargo bay length and volume to define the number of launches, and weight estimates were assessed based on mission requirements and the Orbiter performance. The expendable weights were extrapolated for the desired mission duration. The resulting data were summarized for both launch and landing conditions. These weights were then compared against mission/configuration requirements and the Orbiter performance to assess weight performance margins, Figure 4-4.

The configuration/mission combinations were each reviewed and sorted as to orbital altitude and inclination: these results also are shown in Figure 4-4. Based on preliminary data, 11 configuration/mission combinations exceed the landing weight. Thus, if the Orbiter planned landing weight is not increased, reassignment of equipment to other launches must be investigated.

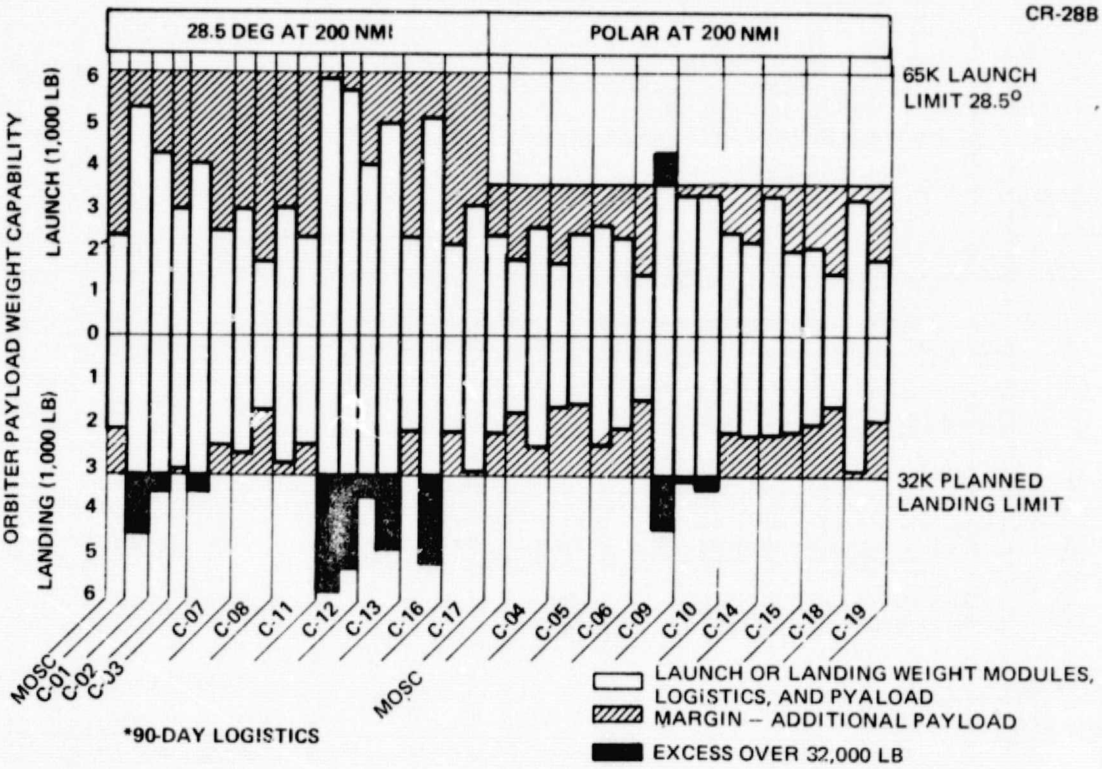

Figure 4-4. MOSC Weight Summary

In order to provide growth capability yet remain within the payload length and weight constraints of the Space Transportation System, the final MOSC configuration will require some degree of modularization. Although many alternative configurations could be pursued, it was found advantageous in previous space station studies to group the functional requirements in terms of logistics, subsystems, payload, and habitability. Each of these requirements could be met by packaging the associated systems and subsystems into separate modules or into combinations. In general, because they are basic to the long-duration station operations, should not require updating or modifications, and can be maintained on orbit, the habitability and subsystems support equipment are best left on orbit.

Six alternative options were analyzed with varying degrees of integration and with two to four modules being considered. Figure 4-5 illustrates alternative configurations considered for the free-flying mode, with the varying degree of integration or functional modularity which previous space station studies have found to be advantageous. Habitability and subsystem support equipment can be left in orbit, whereas research equipment and logistics supplies

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HM HABITILITY MODULE
LM LOGISTICS MODULE
PM PAYLOAD MODULE
SM SUBSYSTEM MODULE

OPTIONS		POSSIBLE INTEGRATION VARIATIONS	GROUND INTEGRATION (COSTS)	MAX. MOSC MODULE LENGTH	LOGISTICS RESUPPLY FLEXIBILITY	EMERGENCY RETREAT	GROWTH BUILDUP
A	ALL MODULARIZED	LM SM HM PM (2)	VERY GOOD	MIN SATIS	EXC	EXC	EXC
B	INTEGRATED SUPPORT	HM/SM LM/PM	GOOD	SATIS	SATIS	POOR	GOOD
C	INTEGRATION FACILITY	LM/SM/HM PM	POOR	TOO LONG	POOR	POOR	POOR
D	SEPARATE SM	LM/HM/PM SM	POOR	TOO LONG	POOR	SATIS	POOR
E	MIXED FCTN INTEGRATION	HM/PM SM/LM	POOR	SATIS	POOR	GOOD	POOR
F	INTEGRATION ORBITAL ELEM	LM SM/HM PM	VERY GOOD	SATIS	EXC	EXC(1)	GOOD

RECOMMENDATIONS:

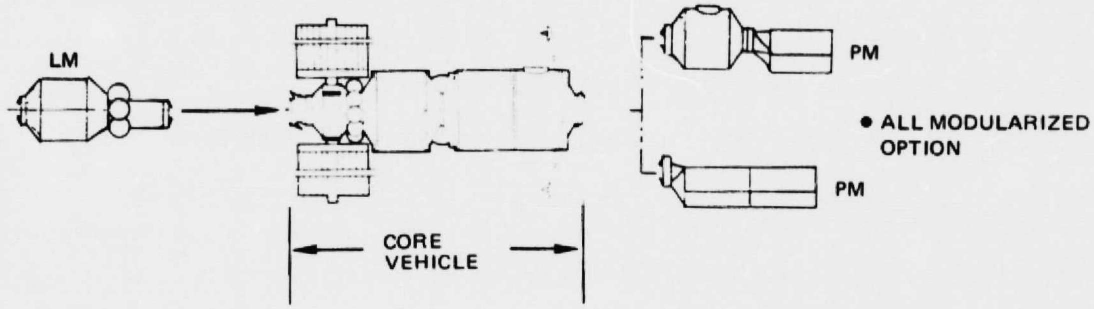
OPTION F PREFERRED

(1) PROVIDING INTERNAL BULKHEADS ARE ADDED
(2) PRESSURIZED OR UNPRESSURIZED

Figure 4-5. Mosc Configuration Options Comparison

must periodically be transported to and returned from orbit. For the reasons noted in Figure 4-5, Option F (see Section 4.2, Vehicle Concept Selection) was recommended as the approach for further examination. This option would incorporate pressurized, dedicated modules for major facility functions. Figures 4-6 and 4-7 show the resultant modular arrangement and plan view of the baseline four-man MOSC vehicle.

Two variations of the basic four-man design were also briefly examined during the study to illustrate alternative configurations meeting special mission requirements. One variation was a small, three-man configuration capable of being delivered to orbit in a single Orbiter launch and providing moderate duration stay times (60 days) on orbit. This facility could be placed in orbits other than the nominal and would represent a low-cost approach to unique or quick-reaction missions. A second variation was a six-man growth configuration in which provisions could be made for maintaining a larger crew on orbit for 90 days or more. This six-man configuration was predicated upon the assumptions that certain future missions might require more manhours in orbit rather than more payload weight. In these



CONFIGURATION FEATURES/RATIONALE FOR SELECTED OPTION

- MODULARIZED BY FUNCTION
- PRESSURIZED SM PERMITS USE OF ORBITER/SPACELAB EQUIPMENT
- SOLAR ARRAY/ORBITER CLEARANCE FOR TWO-END DOCKING
- HAZARDOUS MATERIALS STOWED EXTERNALLY
- DUAL RETREAT VOLUMES AT ALL TIMES
- LM AND EM ATTACHED USING DM AND/OR MANIPULATORS

Figure 4-6. Baseline 4-Man MOSC Vehicle Modular Arrangement

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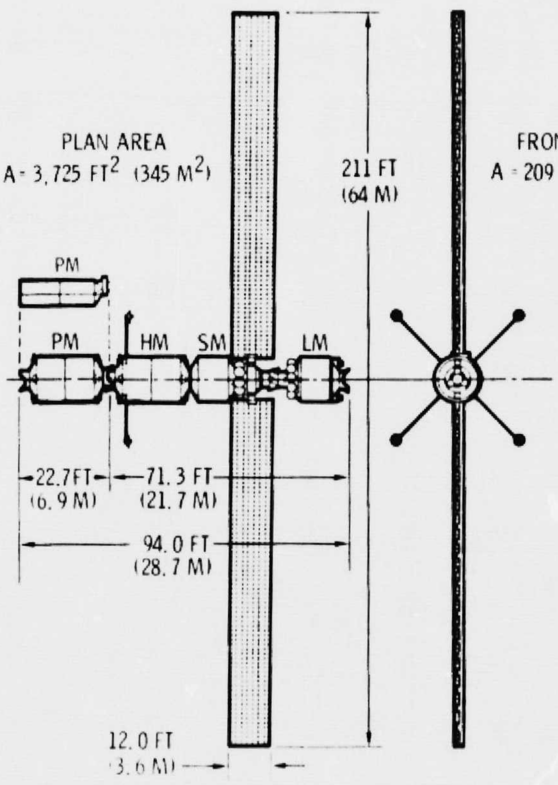

Figure 4-7. Baseline 4-Man MOSC Plan – Plan View

cases, the larger crew would reduce calendar time to accomplish specific research tasks, broaden the skill base available in orbit, spread station-keeping responsibilities, and facilitate multiple three-man, and six-man shift operation. For comparative purposes, profile views and configuration guidelines of the baseline, versions are presented in Figure 4-8 and Table 4-2.

Except for the few variations noted (reference Table 4-3), the subsystems for the three MOSC vehicles are identical in basic design concept and differ primarily in regard to the consumables required and the location.

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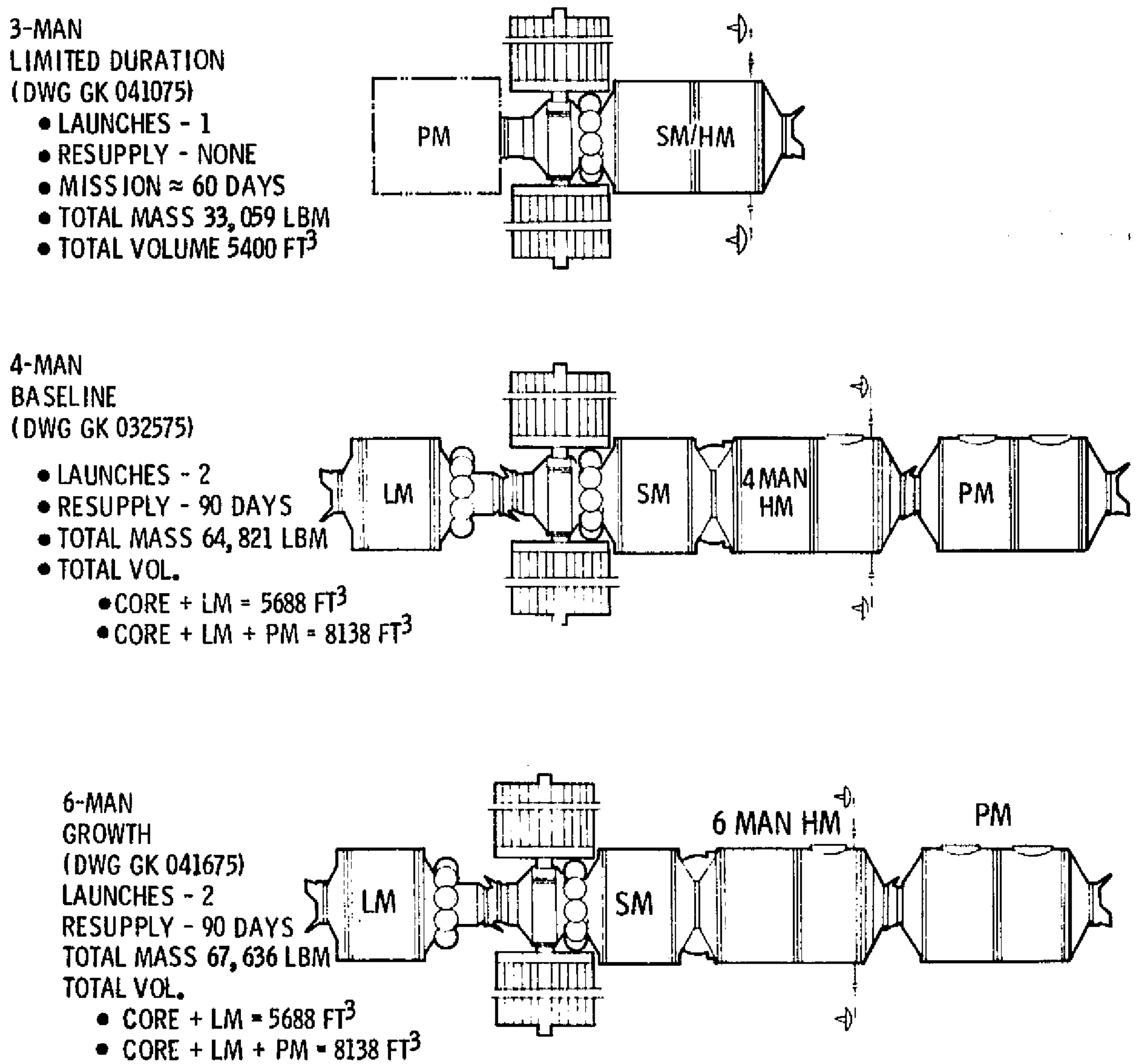

Figure 4-8. MOSC Basic Configurations

Table 4-2

CONFIGURATION GUIDELINES SUMMARY

1. Baseline MOSC
   - Four-man crew
   - Open-ended orbital duration
   - Logistics and payload modules capable of being returned to Earth by the Orbiter
   - 90-day resupply cycle
   - IOC in 1984
2. Limited-Duration MOSC
   - Three-man crew
   - Limited orbital duration - 60 days
   - All modules capable of being returned to Earth by the Orbiter
   - No orbital resupply
   - IOC in 1984
3. Growth MOSC
   - Six-man crew
   - Open-ended orbital duration
   - Logistics and payload modules capable of being returned to Earth by the Orbiter
   - 90- to 180-day resupply
   - IOC in 1984

A more detailed description of the three-man limited-duration concept may be found in Appendix E, and a description of the six-man growth concept may be found in Appendix F.

An increase in the operational and support capabilities of the MOSC can be readily achieved through the addition of a multiple docking capability. To increase the MOSC resources in all operational areas, multiple radial docking ports can be incorporated either in the habitability module, Figure 4-9, or as a dedicated docking module, Figure 4-10.

The installation envelope of the ASTP international docking assembly establishes three radial docking ports as optimum. This is consistent with pre-

Table 4-3

COMPARISON OF ALTERNATIVE MOSC SUBSYSTEMS WITH BASELINE CONCEPT SUBSYSTEMS

Subsystems	3 Man Concept	6 Man Concept
Crew Accommodations	Three crew quarters – combined personal hygiene and waste management free volume reduced(2)	Two crew quarters – added to wardroom(2)
ECLS	Same	Same design but sized for six men
EPS	Same	Same
Data Management – Experiment	Same(1)	Same (1)
Data Management – Vehicle	Same	Same
Communications	Same	Same
Stability/Control	Remove one CMG – 6,000 H	Same
RCS/Propulsion	Ten thrusters located coplanar at HM(2) outboard end	Same(2)
Structural/Mechanical	No EVA airlock	Same

(1)Dependent upon experiment requirements

(2)Consumables adjusted

vious studies of radial docking operational efficiency. Structural countersinking of the international docking assembly (Figure 4-9) or a smaller-diameter pressure shell structure (Figure 4-10) are required to stay within the Orbiter cargo bay clearance envelope.

The option to reconfigure the baseline habitability module and incorporate radial docking ports for additional operations would permit modules at three ports, e.g., (1) long-term experiments, (2) short-term experiments, and (3) logistics or habitability module. A center docking section would provide maximum clearance between end-docked modules and Orbiter radial docking

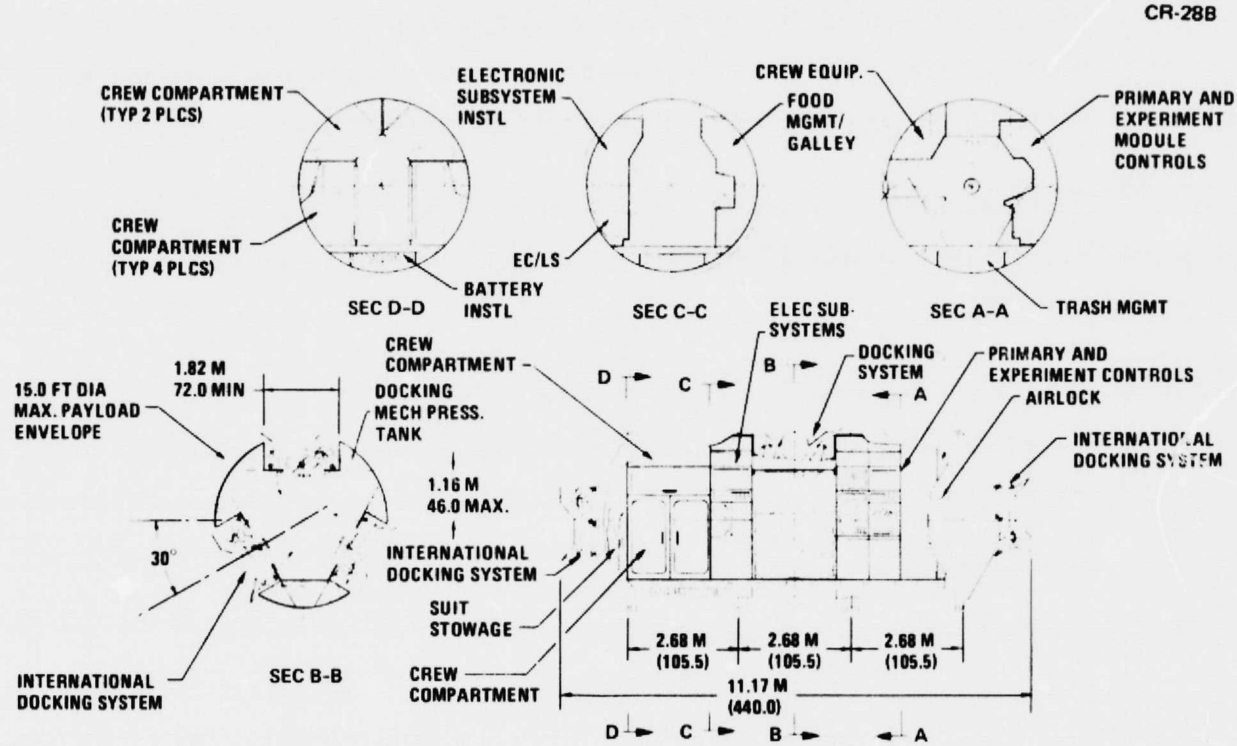

Figure 4-9. 6-Man Habitability Module with 3 Radial Docking Ports

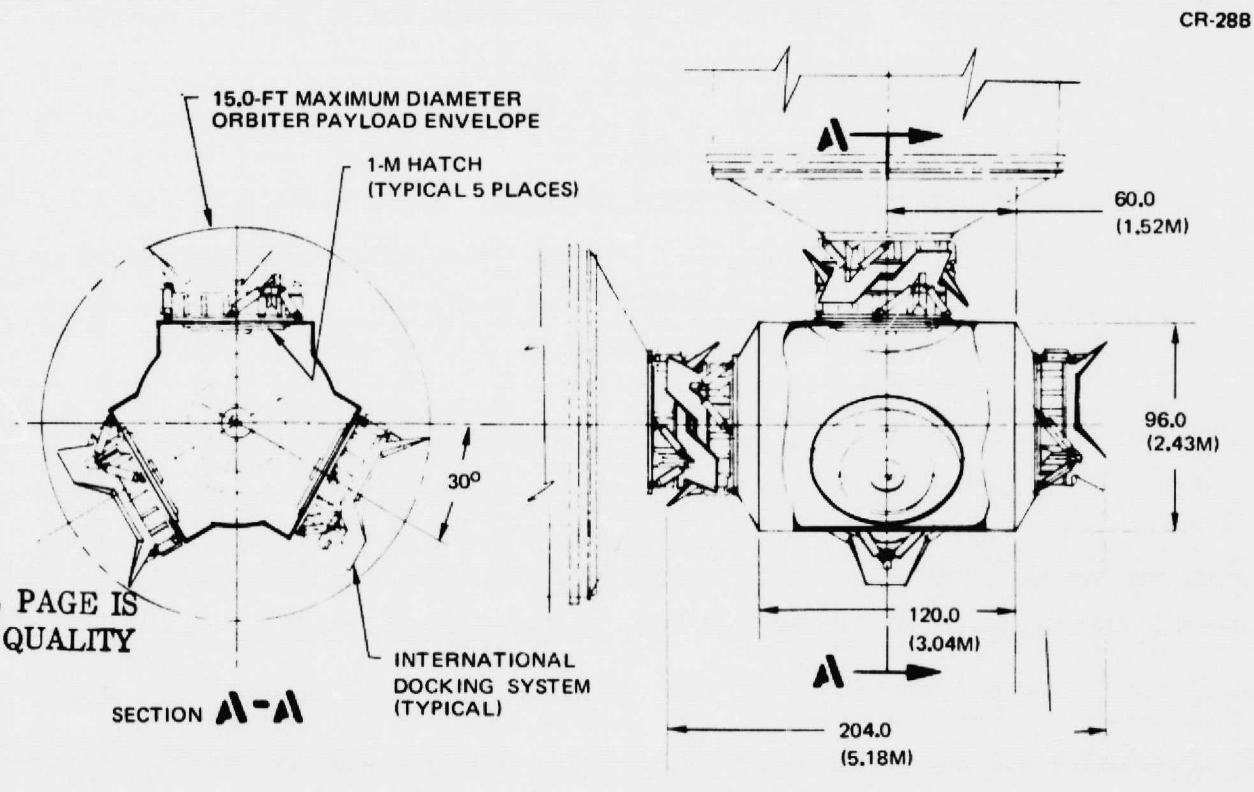

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Figure 4-10. MOSC Docking Module Concept

maneuvers adjacent to the habitability module; three ports could be added and the habitability module would still support a four-man crew. The habitability/docking module could utilize technology being developed for Spacelab, but major structural modifications are required to provide necessary load paths and permit docking assembly installation.

Careful consideration must be given to a dedicated docking module, however, as it may provide greater flexibility by removing crew traffic flow from the habitability module.

4.2 AVAILABLE HARDWARE AND TECHNOLOGY

One of the initial steps in developing the configuration recommendation was to identify subsystem- and component-level hardware that will be available for the MOSC space station design and development. The next step was to examine its applicability, either directly or with modifications, to satisfy payload or subsystem requirements.

This survey included preliminary examination of the hardware articipated as being available from programs operationally concurrent with the projected MOSC mission and predecessor programs, including (1) Apollo, (2) Skylab (OWS, AM, MDA, ATM, etc.), (3) Shuttle-Orbiter, (4) Spacelab, (5) LST, and (6) SEPS. The survey results are as follows:

- Application of component-level available hardware can significantly benefit each major subsystem.
- The preliminary survey identified specific hardware or technology applicable from the Orbiter, Skylab, Spacelab, and SEPS programs.
- Approximately 75 percent of the hardware and/or technology can be selected from available items.

The key areas examined included (1) available subsystems and components, which have demonstrated by previous studies and programs to have high DDT&E costs, (2) adaptability of existing designs to satisfy requirements of long missions, and (3) identification of major hardware items which would have a significant influence on the vehicle configuration.

The use of available subsystem- and component-level hardware can represent a significant contribution toward minimizing the cost of the MOSC program,

and accordingly, is proposed wherever feasible. This rationale and conceptual approach should be capable of successful implementation due to the wide array of flight-qualified hardware to draw from the standard multiyear operational life capability required in the contributing programs.

The MOSC vehicle will have an ideal chronological relationship to maximize the benefits of the Shuttle and Spacelab technology and hardware legacy. In balance, however, the careful assessment of maintaining crew safety standards within the longer-duration MOSC missions, discretionary payload weight tradeoffs, and system growth potential must also be considered. An additional factor which must ultimately be investigated is the production availability of current hardware in the needed time frame.

The use of present Apollo or Skylab hardware may be limited due to its production status, and many stored items would require complete refurbishment because of shelf-life limitations. However, use of hardware manufactured from the proven designs or developed from the design technology can be expected to result in cost savings.

Table 4-4 summarizes a portion of candidate hardware which would be applicable for use on the MOSC. As the MOSC preliminary design progresses to the point where greater subsystem detail is available, additional candidate hardware may be identified. To ensure availability of all items of interest, procurement plans must be formulated.

A preliminary examination of typical Skylab components provided detailed information on the characteristics, which permitted a feasibility evaluation to determine if a component would be applicable. Additional Skylab components are summarized in Appendix C. Table 4-5 identifies selected details of the identified Skylab program hardware.

Considering those subsystems representing the major portion of the program DDT&E costs (Reference Figure 4-11), certain hardware items from other programs are prime candidates for incorporation into MOSC subsystems.

A detailed design analysis and subsystem performance study must be conducted to determine if specific hardware items can be used in a MOSC vehicle.

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Table 4-4 (Page 1 of 2)

MOSC SUBSYSTEMS HARDWARE AVAILABILITY MATRIX

MOSC Subsystems	Program	Hardware	Program	Hardware	Program	Hardware	Program	Hardware
Structural/ Mechanical	Apollo	Crew transfer system	Skylab	Window Supports	Apollo	Docking System		
			Orbiter	Airlock				
	Spacelab	Primary structure - modules	Orbiter	Pressure hatches				
		Secondary structure - floors, racks, etc.						
ECLS	Skylab	Molecular sieve Radiator	Skylab	Fans Radiant heater Refrigerator	Orbiter	Lights Controls	Skylab	Fans Heaters
	Orbiter	Lights Controls	Orbiter	Partial pressure sensors Regeneration system	LST	Portable lights	Orbiter	Lights Controls
	Apollo	Water supply system coolant loop pumps, controllers and valves						
	Spacelab	CO_2 and trace gas assembly Humidity and temperature control assembly Water separation assembly Water pump package Freon pump package						
Crew Accommodations	Skylab	Handholds Tethers	Skylab	Food prep table Lockers	Skylab	EVA lights	Skylab	Handholds Tethers Lockers
	Orbiter	Fire extinguisher	Orbiter	Urine/fecal system Food	Orbiter	Lights	Orbiter	Lights Controls
Power	Apollo	Power conditioning system - inverters and meters						
	SEPS	Solar array Distribution system/batteries	Orbiter	Controls Displays	Orbiter	Controls Displays	Skylab	Batteries
	LST	Solar array Batteries Regulator	Orbiter	Distribution system	LST	Umbilicals	Orbiter	Distribution system
			LST	Umbilicals			LST	Umbilicals

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Table 4-4 (Page 2 of 2)

MOSC SUBSYSTEMS HARDWARE AVAILABILITY MATRIX

MOSC Subsystems	Program	Hardware	Program	Hardware	Program	Hardware	Program	Hardware
Instrumentation and Communications	Skylab	TV system Intercom	Skylab	Multiplexer Sensors	Skylab	Sensors	Skylab	Sensors TV system Intercom
	Orbiter	Transmitter Teleprinter	Orbiter	Controls	Orbiter	Controls	Orbiter	Controls
	LST	TDRS antenna Decoders Couplers	LST	Caution and warning	LST	Caution and warning	LST	Caution and warning
	Apollo	Caution and warning	Apollo	Caution and warning	Apollo	Caution and warning	Apollo	Caution and warning
	Spacelab	Control panels	Spacelab	Control panels	Spacelab	Control panels	Spacelab	Control panels
Data Management	Orbiter	Computer Buffers	Skylab	Tape recorders Signal conditioners		Not applicable	Skylab	Tape recorders Signal Conditioners
	LST	Downlink distributor	Orbiter	Processors Controls Interface units			Orbiter	Converters Processors Controls Interface units
	Spacelab	Tape recorder					Skylab	Tape recorder
Stability and Control	Skylab	Spheres CMGs	Orbiter	Controls Displays		Not applicable	Orbiter	Controls Displays
	Orbiter	Control valves Star tracker						
	Apollo	Guidance and naviga-tion system - tele-scope, sextant, gyro package, accelerometers, and displays	Apollo	Guidance and naviga-tion system - tele-scope, sextant, gyro package, accelerometers, and displays				
Reaction Control	Orbiter	Storage tanks	Orbiter	Controls Displays		Not applicable	Orbiter	Controls Displays
	LST	Thruster module						
	Apollo	Thrusters, tanks and transducers	Apollo	Thrusters, tanks and transducers				
Environmental Protection	Orbiter	Meteoroid protection	Skylab	Film vault Radiation monitors	Spacelab	Radiation shields	Spacelab	Radiation shields Contamination shrouds
Docking	Skylab	Alignment target lights	Skylab	Alignment target lights	Skylab	Alignment target lights	Skylab	Alignment target lights
	ASTP	Docking mechanism	ASTP	Docking mechanism	ASTP	Docking mechanism	ASTP	Docking mechanism
Checkout	Orbiter	Controls Displays	Orbiter	Controls Displays Computer interfaces	Orbiter	Controls Displays	Orbiter	Controls Displays
	Apollo	Rendezvous system radar antenna, ranging units, alignment targets	Apollo	Rendezvous system radar antenna, ranging units, alignment targets	Apollo	Rendezvous system radar antenna, ranging units, alignment targets	Apollo	Rendezvous system radar antenna, ranging units, alignment targets

Table 4-5

SKYLAB PROGRAM HARDWARE CHARACTERISTICS

Source	Hardware/Characteristics	Reference
Airlock Module	Molecular Sieve Gas flow — normal system 34.2 cfm odor removal 29.3 cfm Capacity — 8.6 lb/day of water, 6.75 lb/day of CO_2 at inlet conditions of 52°F dew point and CO_2 partial pressure of 5.5 min Hg Regeneration bakeout uses 390-watt heaters Solids trap — 40 micron screen	SLOH*
Airlock Module	Window 8 in. x 12 in. oval IR reflective with cover	
Orbital Workshop	Window 18-5/6 in. circular IR and UV coated	
Airlock Module	Pressure Hatch 49.5 in. diameter with 8.5 in. window 9-latch system, quick-release pins, equalization value	
Orbital Workshop	Radiant Heater Heat dissipation: 125 watts at 24 Vdc Voltage range: 22 to 28 Vdc Surface temperature: 210°F	
Airlock Module	Tape Recorder Input voltage: 24± 15 VDC Input power: 15.5 watts max Inputs: 5.12 kbps rz and clock 5.76 kbps rz and clock 300 to 3000 Hz audio Outputs: 112.6 kbps nrz — space 126.7 kbps nrz — space 6.6 to 66 kHz	
All Modules	UV Fire Sensors Input voltage: 18 to 33 VDC Input power: 6 watts Sensitivity: 1850 to 2650 A°	
Orbital Workshop	Spheres Volume: 4.5 cu ft Operating temperature: -15P to +175°F Operating pressure: 30° to 3100 psia Proof pressure: 6000 psig Burst pressure: 8000 psig	
Multiple Docking Adapter	Docking Alignment Target Apollo LM type Base diameter: 17.68 in. Self-illuminating	

*SLOH — Skylab Operations Handbook, Document MSC 04720, Vol I.

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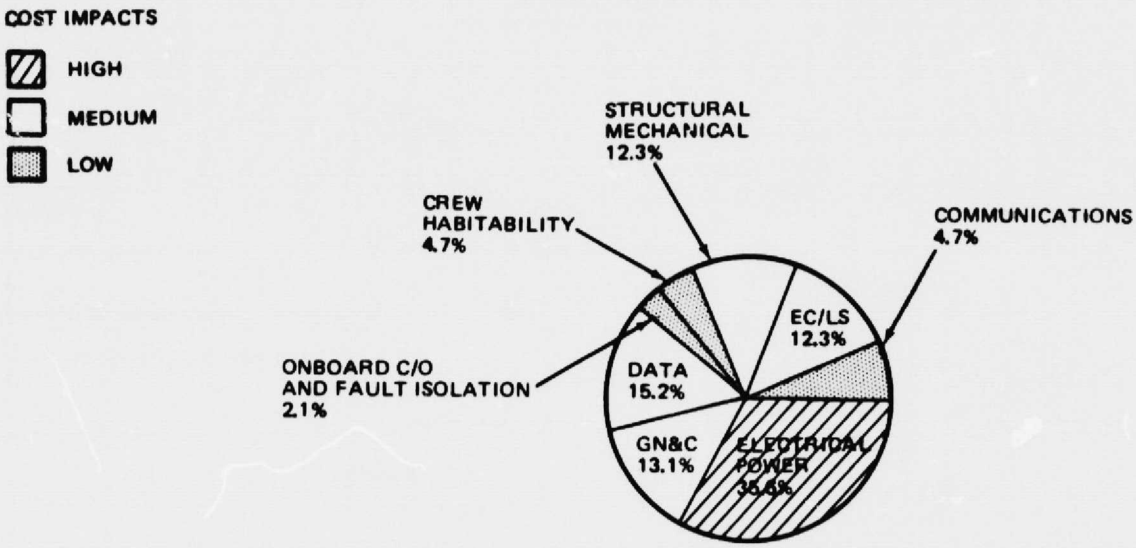

Figure 4-11. Typical Free-Flying Module Subsystems DDT/E Cost Relationship

Specific items must be considered as to their shelf life, preventive maintenance, software availability, and refurbishment program. The costs of these tasks should be compared to the new-item development cost to determine if retention is economically desirable.

The development of a minimum-cost, high-capability space station capable of fulfilling the space program commitments and at the same time achieving complete compatibility with the Space Shuttle will benefit if a sufficiently flexible system can be based on available hardware. The necessary basic submodular and subsystems elements are, to a significant degree, readily available from the Shuttle, Spacelab, SEPS, Skylab, and Apollo hardware and technology.

4.2.1 Spacelab Hardware

The primary hardware to be utilized in generating the full range of MOSC concepts was the submodular structural elements. A submodule approach was used to ensure full and universal application of these important building blocks and to minimize the possibility of constraining the freedom of variation in

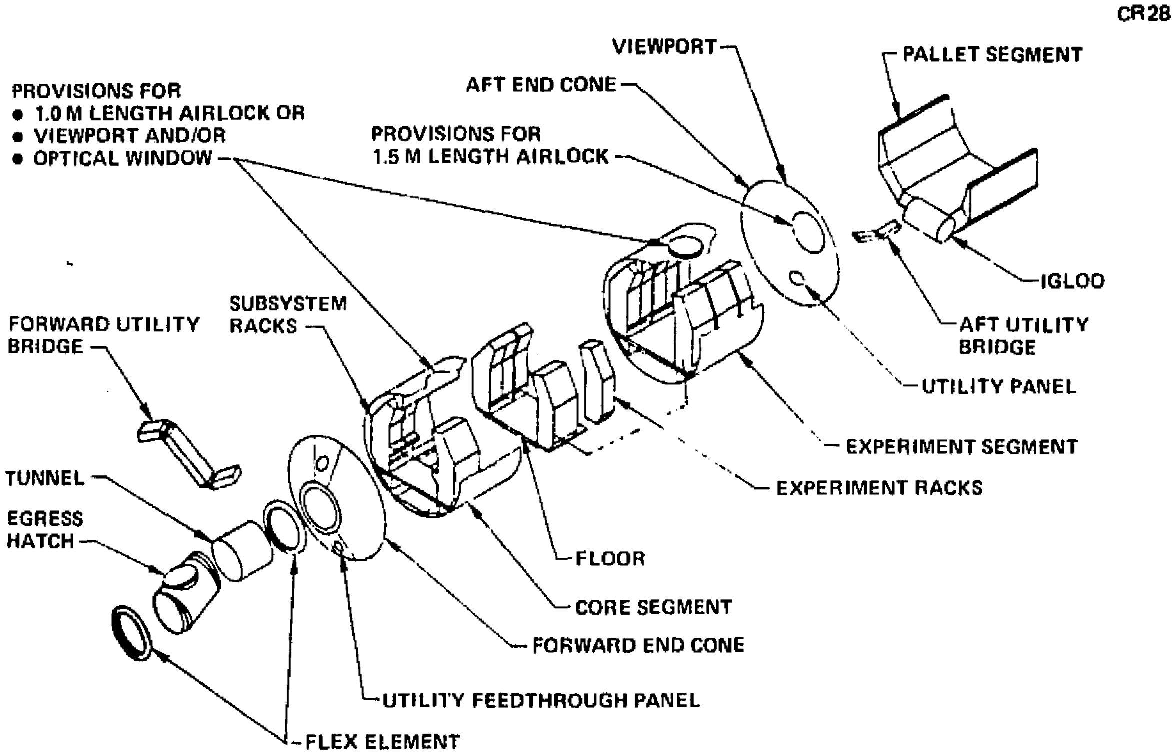

Figure 4-12. Major Spacelab Elements

creating modular arrangements. The basic structural building blocks of the Spacelab are shown in Figure 4-12.

The most significant available hardware benefit from Spacelab would be the primary structure, which possesses the inherent flexibility of modular elements, thus permitting the selective rearrangement to accommodate specific requirements. In addition, the Spacelab being designed as an Orbiter payload ensures dimensional and installation compatibility. However, the MOSC's different modular grouping may require that a modified support structure be considered to match the Orbiter's cargo bay payload support points. The autonomous removable feature of the secondary structure does not appear as readily adaptable to the MOSC requirements of (1) pressure shell interior surface inspection, (2) vented compartments for battery installations, and (3) the integration of crew accommodations.

The following two major Spacelab elements were selected to develop MOSC configurations:

<u>Cylindrical Section</u> - This cylinder is fabricated from 2219 aluminum in the

T condition, and is flanged at both ends for mating to additional sections or the end domes. The basic manned module assembly consists of two sections on Spacelab; however, current design would probably permit assembly of three sections. The basic module with one cylindrical section and end domes is designated the "short module," and the two-cylindrical-section module with end domes is designated a "long module." Soft seals are used in dual sealing grooves in the end flanges. External support trunnions are located just above the horizontal centerline, and a keel fitting for absorbing lateral loads is located on the vertical centerline.

End Dome — The Spacelab end dome has a matching bolt flange to the cylindrical sections but would require modification for internal application as a double-bulkhead EVA airlock reverse-pressure bulkhead and to accommodate the installation of the Apollo-Soyuz Test Project (ASTP) international docking assembly.

4.2.2 International Docking Systems — ASTP

The ASTP mission in July 1975 will flight qualify this unit at the Apollo and Soyuz spacecraft mass levels and docking dynamics. This mass level of approximately 35,000 pounds for the Apollo Spacecraft is almost an order of magnitude less than the Orbiter at approximately 215,000 pounds and the MOSC at 32,000 pounds to as much as 100,000 pounds. Although the international docking system docking velocity limit requirements of 1 ft/sec axially and 1/2 ft/sec laterally are compatible with the Orbiter's performance (i.e., 0.5 ft/sec axially and 0.25 ft/sec laterally), the effect of the greater momentum must be analyzed in detail. The basic concept is valid and applicable to MOSC, and the required strengthening should not represent major modifications. The docking system is shown in Figures 4-13 and 4-14.

4.2.3 Evaluation/Characteristics

As a means of orientation, Table 4-6 is presented to summarize the pertinent and influential factors of the basic Spacelab and MOSC missions and spacecraft. This information provides an analytical overview of the Spacelab (attached mode) and the two basic MOSC free-flying vehicles. Relevant data from subsequent sections and the other books have been included to permit review of the salient points. Detail information and discussions are contained in the respective sections of this report.

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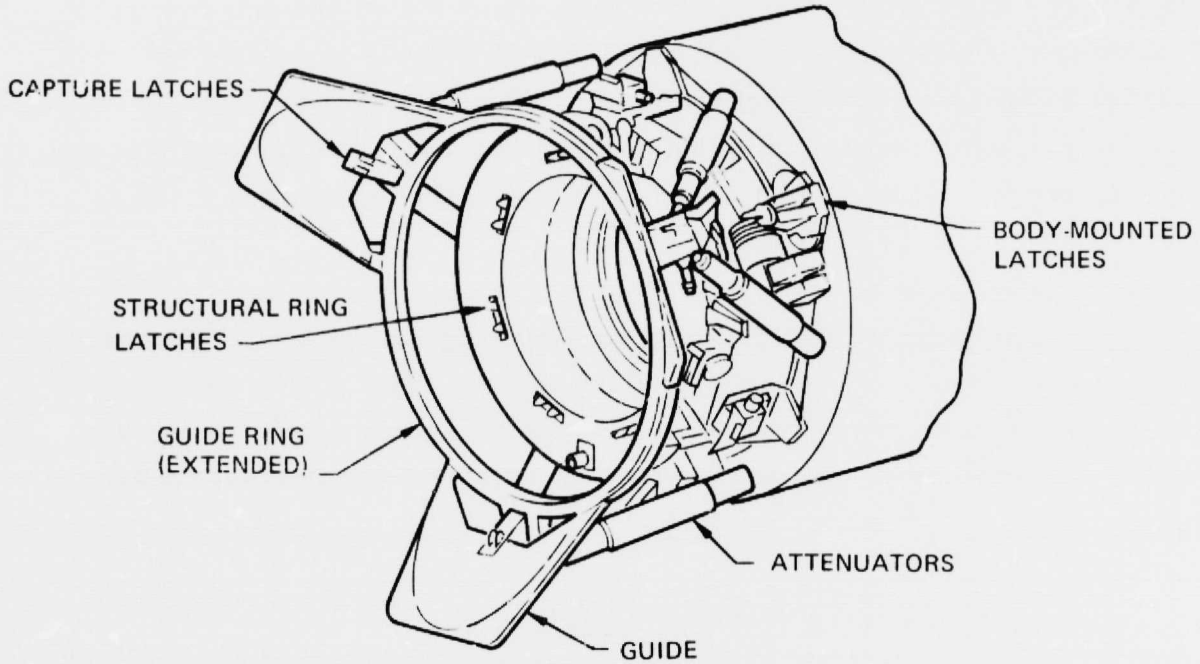

Figure 4-13. International Docking Mechanism

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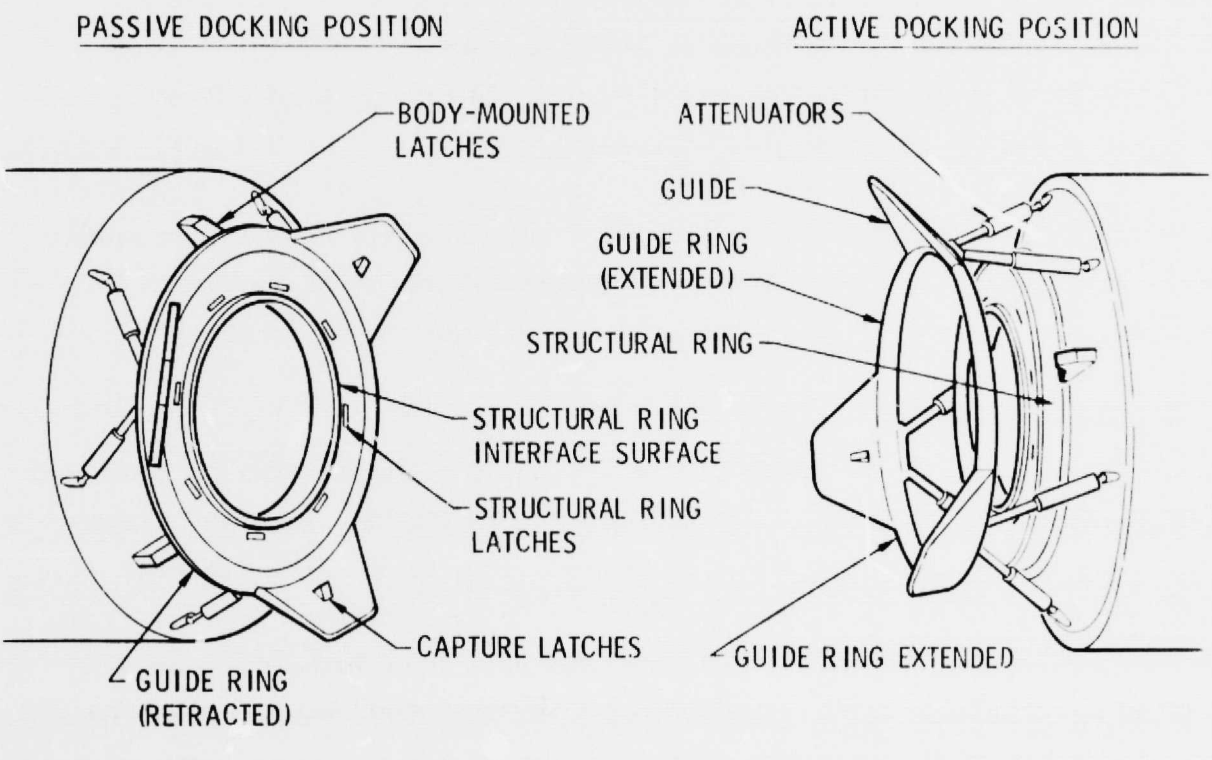

Figure 4-14. International Docking System Operation Schematic

Table 4-6 (Page 1 of 3)

MANNED ORBITAL FACILITY

CONCEPT CHARACTERISTICS SUMMARY

	SHUTTLE-ATTACHED	FREE-FLYING	
Concept Characteristics	Spacelab	MOSC (Limited Duration)	Baseline MOSC (Long Duration)
Mission Plan	• Short duration • 7-day operations • Potential growth to 30 days (undefined)	• Semi-permanent • 60 days maximum on orbit • Deliver/retrieve each module/payload • Each flight unique	• Permanent facility(s) extended duration ≈ 5 years • 90- to 180-day logistics flights (crew exchange/resupply consumables) • 90-day to "as required" payload flights
Nominal Experiment Program - Manhours (SSPDA)	37,000	37,000	37,000
Experiment Support/Responsiveness			
• No. of Payloads (SSPDA)	42	42	42
• Payloads added in MOSC Study		4	4
• No. of Combinations	—	19	19
• Experiment Program Accomplished	100%	100%	100%
• On-Orbit Experiment Manhours Required	58,000	38,000+	38,000
• Accomplish Future Goals (e.g., Space Manufacturing Limited Production)	None	Interrupted - Limited Duration	Continuous - Unlimited Duration

Table 4-6 (Page 2 of 3)

CONCEPT CHARACTERISTIC SUMMARY

Concept Characteristics	Spacelab	MOSC (Limited Duration)	Baseline MOSC (Long Duration)
Flight Program Implementation Effectiveness			
• No. of Shuttle Flights	230	144	69
• New Hardware Required	None	2 facilities	2 facilities
Growth Aspects			
• Duration			
Total Mission	30 days max.	60 days max.	5 years
Crew	30 days max.	60 days max.	90 days up to man's capability
• Payload	65K up - 32K down	Multiple flights	Multiple flights
• Larger Stations (Crew)			4 to 6 to approx. 12
• Adv. Higher Orbit Missions (Synch.)	Orbiter-limited	Provides basic hardware	Provides basic hardware and orbital support
• Space Assy. Support	Limited by duration	Limited by operations	Suitable for: - Tug refueling and refurbishing - Large-area space structures

Table 4-6 (Pages 3 of 3)

CONCEPT CHARACTERISTICS SUMMARY

Concept Characteristics	Spacelab	MOSC (Limited Duration)	Baseline MOSC (Long Duration)
<u>Man Utilization and Accommodation</u>			
• Crew Size	1 to 4	2 to 4	4 to 12
• Crew Habitation	Orbiter ≈ 800 ft^3	2,450 ft^3 habitability/ subsystems module	2,450 ft^3 habitability module
• Crew Stay Time On-Orbit Max. Days	30	60	90 and up
• Skill-Cross Training	Not critical	Mandatory	Mandatory
• Utilization	Experiment operations	Experiment operations Facility operations Limited maintenance and repair	Experiment operations Facility operations Maintenance and repair Logistics handling
<u>Mission Responsiveness and Flexibility</u>			
• No. of Flights	230	144	69
• Orbit Selectivity nmi.	(100 to 350)	(100 to 350)	(100 to 350)
• Facility Duration On-Orbit Capability (Max.)	30 days	60 days	5 ± years
• Launch Rate (Max.) Per Year (Avg.)	30 29	34 21	16 10
• Traffic Interference Potential	High	Medium	Low

Section 5
BASELINE 4-MAN MOSC DEFINITION

The vehicle conceptual definition involved the following steps and information: (1) selected concept and general modular arrangement from Task 2, (2) the determination of selected subsystems volumes and weights, (3) the placement of internal equipment and stowage to establish a preliminary internal volume assignment, (4) a weight and center-of-mass analysis, (5) a safety and operational procedure assessment, and (6) the development of a conceptual inboard profile.

5.1 OVERALL CONFIGURATION

The baseline 4-man MOSC configuration is composed of a two-module core vehicle supported by a logistics module and variable payload modules and/or pallets. End-docking accommodations are provided for all modules, and at least four modules must be docked to complete the MOSC orbital facility as shown in Figure 5-1.

5.1.1 Outboard Profile and Description

The primary items of candidate hardware and/or technology which make a major contribution to the configuration include (1) Spacelab primary structure, (2) SEPS solar array and (3) ASTP international docking assembly. Approximately 75 percent of the subsystems' components will be either available as qualified hardware or will be developed from existing technology.

The general arrangement and module relationships are based on the logic of a core vehicle providing all basic vehicle crew accommodations and vehicle/payload support. Thus, with the core assembly being able to remain in orbit, the end modules which provide additional stores, equipment, or payloads be readily docked and undocked for replacement during the nominal 90-day Orbiter resupply mission. The habitability module docking port is shown with a pressurized payload module; however, this port would also accommodate unpressurized payload pallets.

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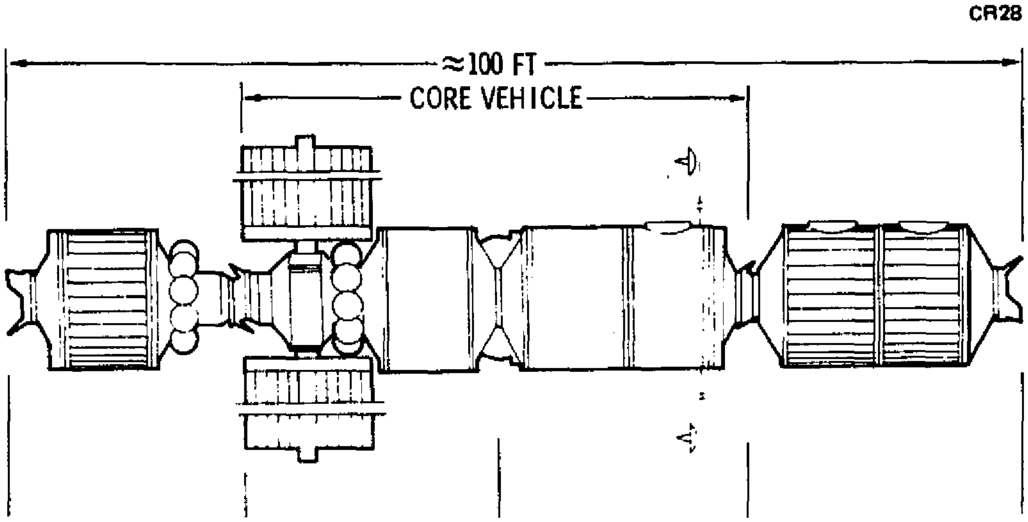

ELEMENT	LOGISTICS MODULE (LM)	SUBSYSTEMS MODULE (SM)	HABITABILITY MODULE (HM)	PAYLOAD MODULE (PM)
FUNCTION	FLUID SUPPLY, BULK CARGO, WASTE STORAGE	ELECTRICAL POWER, STABILIZATION, COMMUNICATIONS, HYGIENE	LIVING QUARTERS, PAYLOAD MONITORING STOWAGE, GALLEY	EXPERIMENTS, APPLICATIONS
LENGTH (FT)	22.7	25.8	24.7	11.5 – ≈ 60
WORKING VOLUME (FT^3)	1,618	1,620	2,450	1,500 – ≈ 5,000

Figure 5-1. Baseline 4-Man MOSC Outboard Profile

The selected baseline vehicle configuration would require two Shuttle launches to place the modules in orbit. The assembly operations profile is shown in Section 6. The first and second launch Orbiter cargo bay installations are shown in Figure 5-2. The baseline configuration's modular arrangement requires a launch sequence which would deliver the core vehicle (habitability and subsystems modules) on the first launch. A nominal period of four days would be required to deliver the core vehicle, deploy the core vehicle, check out all systems either attached or unattached to the Orbiter, and return to Earth.

Assuming a typical ground turnaround time of 7 days for the Shuttle transportation system, on the eleventh day the second launch of the Orbiter would deliver the logistics module and a payload module. These modules would be docked to the core vehicle, crew transfer and complete subsystem checkout would occur, and the Orbiter would return to Earth on approximately the fifteenth day, leaving the MOSC operational in orbit. The core vehicle will have an automatic stabilization capability for the unmanned periods during initial vehicle buildup. The development of detail crew transfer timelines

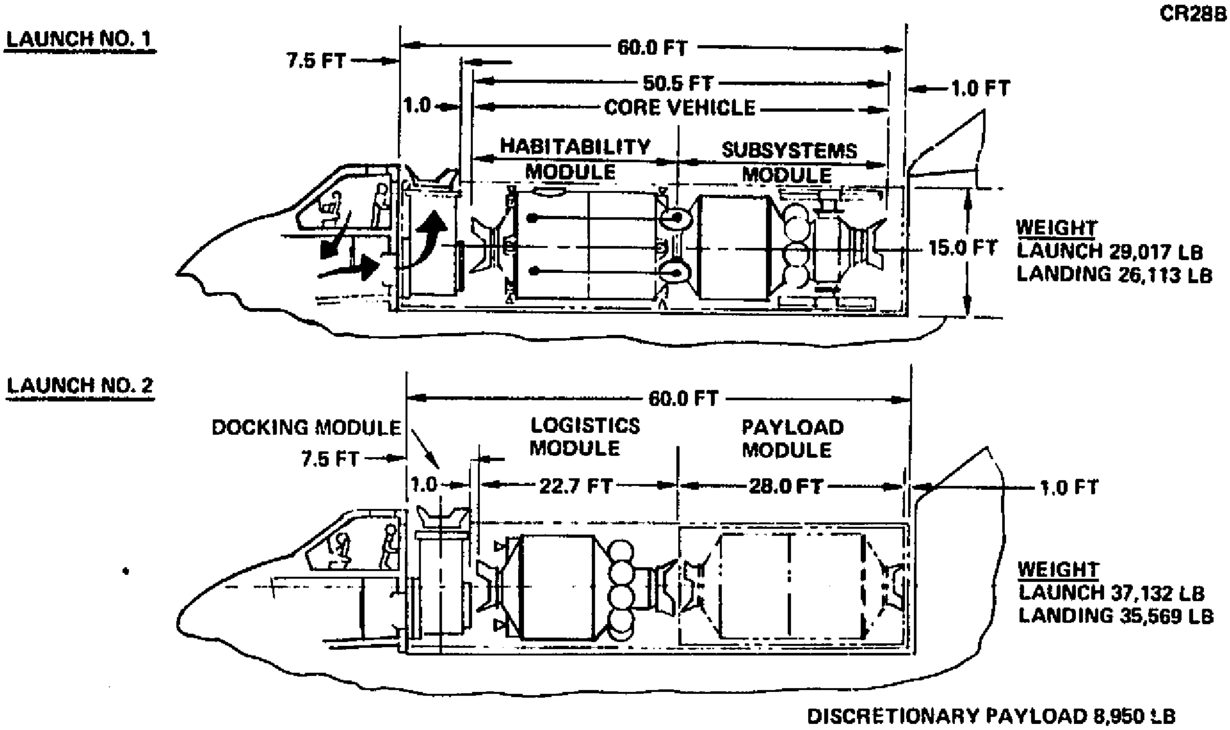

Figure 5-2. Baseline 4-Man MOSC Orbiter Cargo Bay Installation

and module replacement safety requirements will determine the crew's locations during these repeated operations. The modules shown installed (Figure 5-2) for the second launch are typical. Although the logistics module would be a standard configuration, the payload modules will vary in length and may have attached pallets. There also will be pallet-only payloads which might require the entire Orbiter cargo bay length. The core vehicle's external envelope leaves sufficient axial clearance (approximately 2 feet) for safe installation and removal in orbit. There should be sufficient longitudinal adjustment of the modules to permit mating with existing Orbiter attach points. If the Orbiter docking module is required for all launches, the maximum longitudinal dimension of a Shuttle payload is limited to 52.3 feet. The habitability and subsystem modules will be launched together and will remain in orbit; therefore, a docking assembly is not required between them, and a permanent joint will be made on the ground.

5.1.1.1 Vehicle Sizing

Establishing a suitable and efficient volumetric envelope for a manned vehicle is dependent on two independent and possibly divergent constraints: (1) necessary internal free volume for the working, living, and recreation

of the crew, and (2) the external envelope as constrained by the installation dimensions of the launch vehicle. Balancing these two limits to achieve a satisfactory resultant configuration is of paramount importance. The long manned mission durations (i.e., 90 days) are demanding upon the physical well being and tolerance of the crew; therefore, the relative freedom of activity and a personal privacy that is ensured by adequate free volume is most important.

In the baseline MOSC configuration, sufficient latitude was available to provide the required free volume and still be within the Orbiter cargo bay installation envelope.

5.1.1.2 Manned Volume Requirements

Providing sufficient free volume for efficient operations with a reasonable degree of comfort for the crew requires consideration for all open or free volume in the habitability area. Based upon MSFC Standard 512, Man/System Design Criteria for Manned Orbiting Payloads, MOSC sizing requirements were derived for three-, four-, and six-man crews. As shown in Table 5-1, the minimal total assigned volume per crewman should total approximately 200 ft^3 or 800 to 1,000 ft^3 for the four-man baseline. The volume totals in Table 5-1 show adequate volume to accommodate three or four crewmen in a long module. In both cases, there is a significant residual volume available for the necessary equipment, passageways, and some non-habitability functions. To determine the total volume required for a habitability module, it is necessary to estimate the volume required by the crew-support equipment. Based on hardware installation experience and preliminary space station designs, equipment installation density is about 60 percent of module volume. Therefore, with a crew requirement of 800 to 1,000 ft^3, and a 60 percent equipment installation efficiency, approximately 1,200 ft^3 are needed for equipment, or a total module volume of 2,000 ft^3. The baseline four-man MOSC habitability module was sized for 2,450 ft^3 using the dimensions of a Spacelab long module. This initial sizing analysis ensured that sufficient free volume was available; however, during the layout of the internal arrangement, an additional factor was introduced. Applying Skylab experience, the personal hygiene compartment was moved to the subsystems module in order to separate it from the crew's quarters.

Table 5-1

CREW SYSTEMS HABITABILITY VOLUME REQUIREMENTS[1]

Activity	Free Volume (in ft^3) 3 Men	4 Men	6 Men
Sleeping	240	320	480
Eating/wardroom	350	450	650
Personal hygiene			
Cleaning	85 combined	70	70
Waste management		70	70
Habitability volume	675	910	1,270
Total volume available	≈1,250[2]	2,450[3]	2,450[3]
Volume available for equipment, passageways, and other non-habitability functions	585	1,540	1,180

The volumetric equipment density was maintained by moving the payload control console into the habitability module, which coincidently is a preferred location adjacent to the payload module. The personal hygiene volume requirement for three crewmen includes both body cleansing and waste management combined into a single 85-ft^3 volume. For crews of four or more, separate hygiene and waste management compartments should be provided; however, body cleansing can be done in the free volume of the adjacent passageway, which adds an equivalent volume of 85 to 100 ft^3. This is based on experience with the Skylab waste management compartment.

Interior clearance envelopes for crew IVA have been established for traffic paths. For passageways and doorways the height requirements vary from 70 inches for passageways to 60 inches for doorways for both unsuited and suited crewmen. The width for both cases varies from 22 inches for a single, shirt-sleeved crewman to 34 inches for either a pressure-suited crewman or two crewmen in shirtsleeves. The smallest MOSC passageway is 80 inches high and 48 inches wide. The doorway to the crew quarters is 70 inches high and 36 inches wide. Tunnels should be at least 1 meter in diameter. The MOSC solar array tunnel is 1.2 meters minimum diameter. However, the

international docking assembly has an open hatch diameter of approximately 31.5 inches (0.80 meter). Further evaluation of the traffic pattern and the acceptable clearance envelope for long-duration missions must be made.

5.1.1.3 External Envelope Requirements

A rigid constraint is imposed on vehicle external dimensions when, as in the MOSC case, the launch vehicle has an inviolate configuration, and payload installation envelope. However, installation layouts of the Orbiter cargo bay determined that the 15.0-foot diameter by 52.5-foot-long available envelope would house the 2,450 ft^3 habitability module which is approximately 25 feet long and leaves 27 feet for installation of additional equipment/modules. The baseline four-man vehicle also includes subsystems, logistics, and payload modules. To launch the four modules for the initial orbital assembly, two Shuttle launches are required on both a total payload weight and volume basis. The subsystems module was selected for launch with the habitability module to create a core vehicle containing all the manned and station support functions. Thus, in the available 27 feet, conceptual layouts determined that a subsystem module and solar array could be installed with 2-foot clearance between core vehicle and Orbiter cargo bay.

5.1.2 Inboard Profile

The internal arrangements and key module equipment locations are shown in Figure 5-3*. The configuration illustrates a payload complement comprised of two long modules, each dedicated to a different research program. The overall vehicle length is approximately 130 feet, with an internal pressurized volume of 10,500 to 11,000 cubic feet. Based on Skylab experience, the crew could traverse the full vehicle length in 20 to 30 seconds in an emergency and 30 to 40 seconds under normal activity conditions.

The daily crew activity and primary traffic pattern would be concentrated about the habitability module. The logistics module will be visited only periodically to obtain or transfer consumables or other cargo. The galley has accommodations for storing 7 days' worth of food, and each of the crew's quarters has storage for personal gear. These storage arrangements

*An engineering drawing of the inboard profile appears at the end of this section.

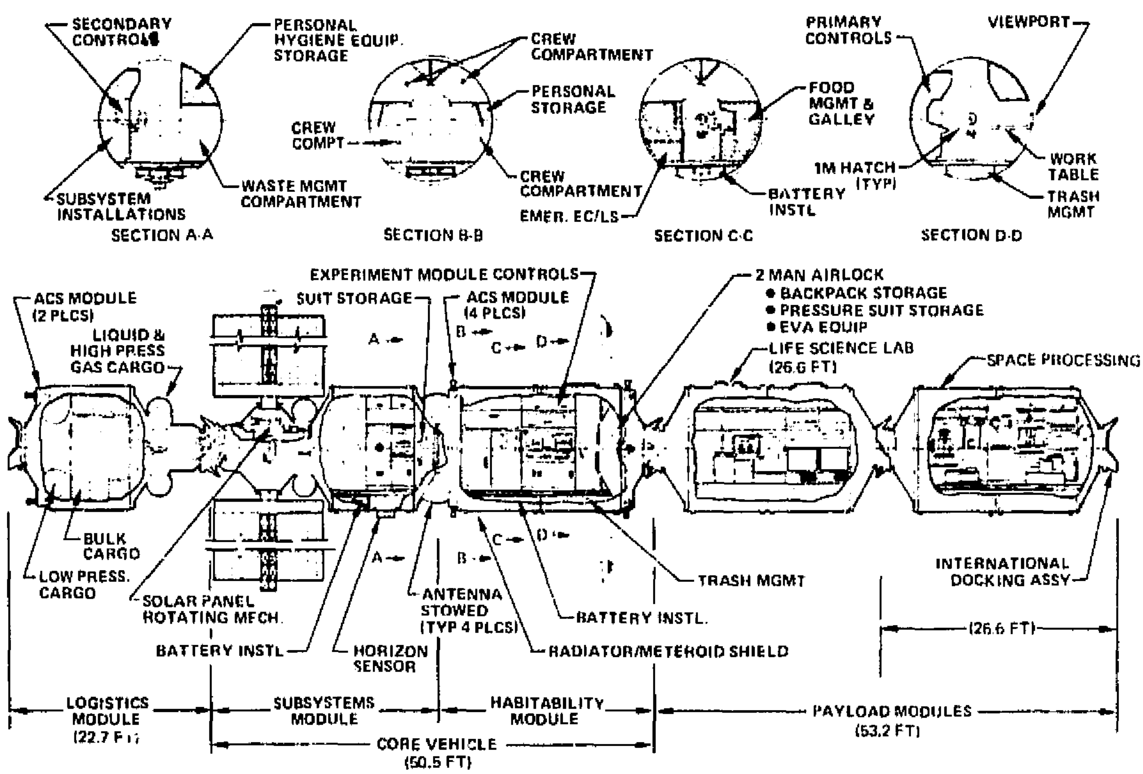

Figure 5-3. Baseline 4-Man MOSC Configuration

would serve to reduce crew traffic through the tunnel. The subsystems activity has been removed from vicinity of the payload modules and an experiment module control station has been placed opposite the wardroom in the habitability module. The internal volume in the core vehicle allows for free volume between the experiment control console and the EVA airlock bulkhead to accommodate traffic flow and physical conditioning activities.

5.1.3 Module Descriptions

The core vehicle, which is the combination of the habitability module and the subsystem module, represents the functional support unit of the baseline vehicle. It is assembled as a unit on the ground, checkout out, launched as a unit, and remains in orbit for the duration of the MOSC program, i.e., approximately 5-years. Therefore, a decision was made to use a bolted joint between the habitability and subsystem modules and eliminate the docking assembly. This reduces the core vehicle length approximately 24 inches, which increases the axial clearance between the core vehicle and the Orbiter cargo bay to an acceptable dimension. In addition, it reduces the core vehicle's weight by 1,800 pounds. The bolted joint can be leak checked and

fully sealed during ground assembly checkout. A second decision concerned the location of solar array rotational mechanism and storage volume for the solar arrays in the retracted conditions. A small-diameter tunnel attached to the SM was selected. The modular arrangements which have been considered for locating the tunnel were (1) between the HM and SM, and (2) outboard of the SM. The significant design and operational pros and cons of each location are tabulated for ready correlation in Table 5-2.

Table 5-2

CORE VEHICLE TUNNEL LOCATION

Tunnel Between SM/HM	Tunnel Outboard in the SM
• Longer core vehicle by approximately 18 inches	• Sufficient cargo bay installation clearance
• Solar arrays located away from both docking ports	• Solar arrays can be rotated/oriented to assure ample docking clearance at tunnel docking port.
(Solar arrays may have to be retracted for protection from Orbiter docking thrusters.)	
• Cabin air leakage through solar array rotating seal failure could require isolation of tunnel and and therefore, the subsystems module	• Under emergency conditions, the tunnel and logistics module can be isolated without imparing crew safety.
• Solar could cause IR heating of radiators and it is also closer to the antennas which could cause transmission interference	• Solar array IR heating of radiators would be minimized as would antenna pattern interference

The inboard profiles of the habitability and subsystem modules are shown in Figures 5-4 and 5-5.

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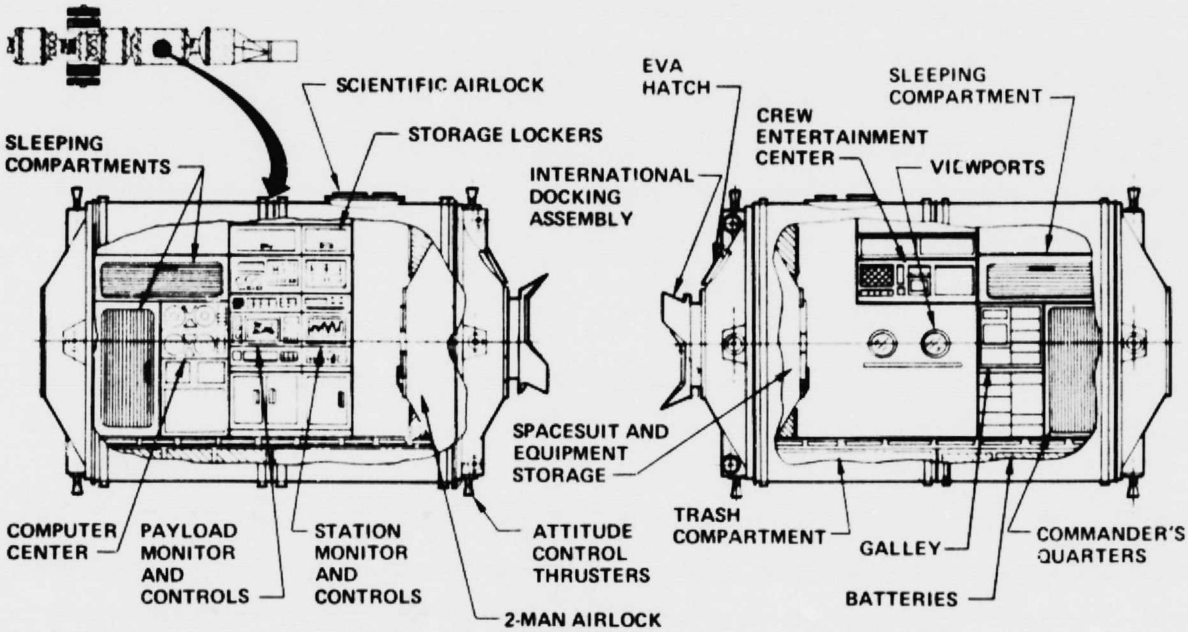

Figure 5-4. Baseline 4-Man MOSC Inboard Profile – Habitability Module

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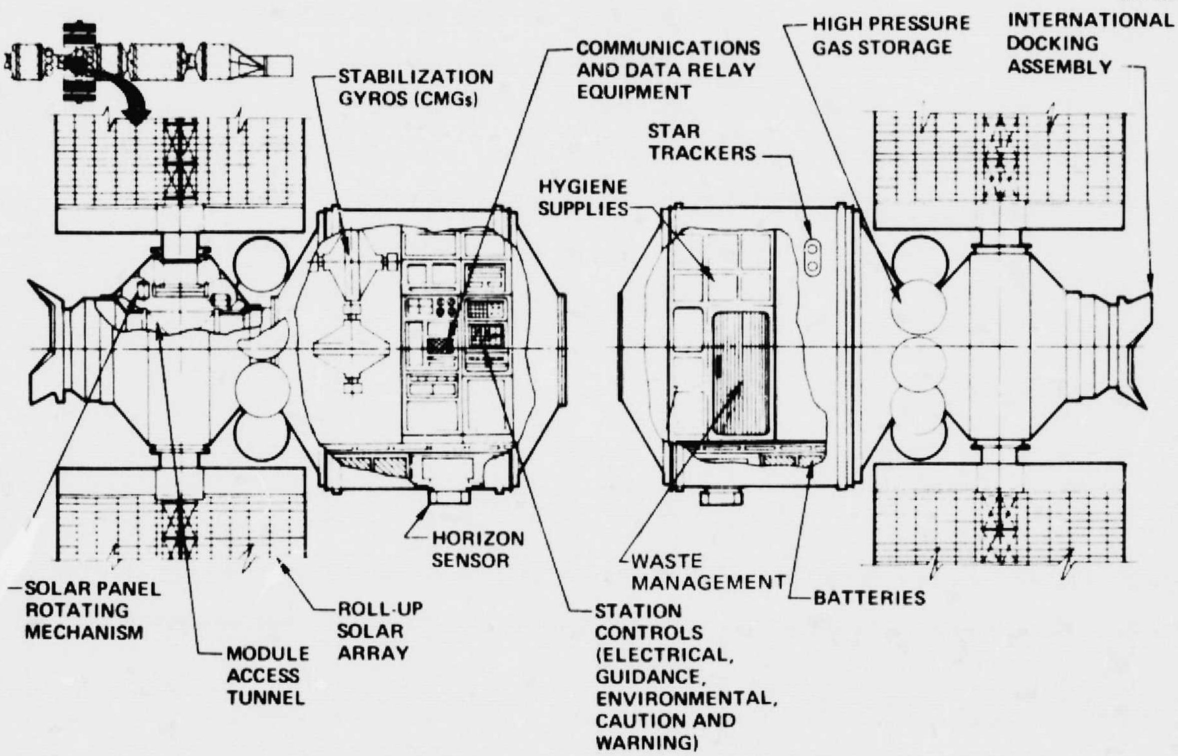

Figure 5-5. Baseline 4-Man MOSC Inboard Profile – Subsystems Module

The internal arrangements and major equipment locations are called out in the inboard profiles. Several points of emphasis are discussed on specific details. The crew has been allocated approximately 250 ft.^{3} each. This includes the individual crew quarters, ward room, and a combined free area for physical activity and exercise. The crew quarters are similar to Skylab and have 80 to 100 cubic feet each. The payload monitor and control consoles are located adjacent to the payload module. This minimizes the interface distance and locates the payload specialist as close as possible to the production and research equipment.

The vehicle control panel is adjacent to the commander's quarters, as a precaution in the event of emergency.

The final element is the two-man EVA airlock, which is located at the outboard end of the habitability module. The preliminary concept uses a module end dome, reversed in orientation and reinforced for reverse pressure. This airlock location serves the following purposes: (1) as an EVA airlock through the use of the EVA hatch, (2) as an emergency egress adjacent to the crew's quarters, (3) as an entry airlock to the payload module for entry of an inspection team in the event of a hazardous condition requiring the isolation of the payload, and (4) to provide EVA access to pallet-mounted payloads by the most direct route. There is a procedural effect, however, which must be evaluated in more detail. The in-line module configuration places the EVA airlock between the core vehicle and the payload module thus during an EVA, egress from the payload module is blocked. Therefore, occupation of the payload module during EVA would probably be prohibited. Since EVA should take place at the most, once in every 5 to 20 days, this should not constitute a major problem.

The subsystems module has sufficient volume and internal surface for installation of all of the subsystems equipment. In addition, the waste management compartment is located there separating it from the crew quarters' sleeping area. (The noise and vibration disturbance of the waste management system was noted by the Skylab crews.) Sufficient clearance has been allowed in the central passageway for rollout racks and cabinets. This allows access to the rack-mounted equipment and also to the inner surface of the pressure shell for leakage inspection and repair.

The Logistics module is relatively inactive inasmuch as its main function is storage and to support the transfer of station supplies. It also serves to return hard data and the accumulated trash to Earth. It is supplied with necessary support equipment and in addition is ideally located on the orbital vehicle to serve as the propulsion module for orbit keeping and, if required, to provide altitude change capability. If additional propulsive energy is required, there are suitable locations for additional propellant and pressurant bottles. The short tunnel allows for the external mounting of high-pressure bottles while still remaining within the Orbiter cargo bay's clearance envelope. Standard racks and cabinets are coded for organized sequential periodic transfer of consumables. There is sufficient volume in this module which, in conjunction with rearrangement of storage accommodations, would permit extending the 90-day logistics cycle by furnishing additional supplies or modifying the interior to accommodate two additional crew quarters.

The Logistics module also is a major element of the crew emergency and rescue plan. As it is an end module of the space station, it would provide one of the two available docking ports for emergency docking of the Orbiter or a backup EVA airlock for this type of rescue operation. One of the two emergency crew support pallets would be located in this module in case it became necessary for the crew to retreat to an end module under emergency conditions. Figure 5-6 shows the inboard profile of the logistics module.

The basic payload module, as defined in the MOSC Study, consists of the pressure shell floor, ECLS ducting, and interface connections for the support subsystems. The detail internal subsystem arrangements are payload dependent.

5.1.4 Hardware Tree

The major organizational system around which the programmatic (schedules and costs) analysis reported in Book IV is developed is a five-level work breakdown structure (WBS). Therefore, the discussion of the MOSC subsystems is presented in the form of a hardware tree in order to provide continuity between the programmatic analysis and the subsystem discussions. In the MOSC study, the WBS was extended to the subassembly or assembly group level. These individual assembly group diagrams directly relate the primary WBS to the subsystem definition and the mass characteristics breakdown in the mass properties summary tables.

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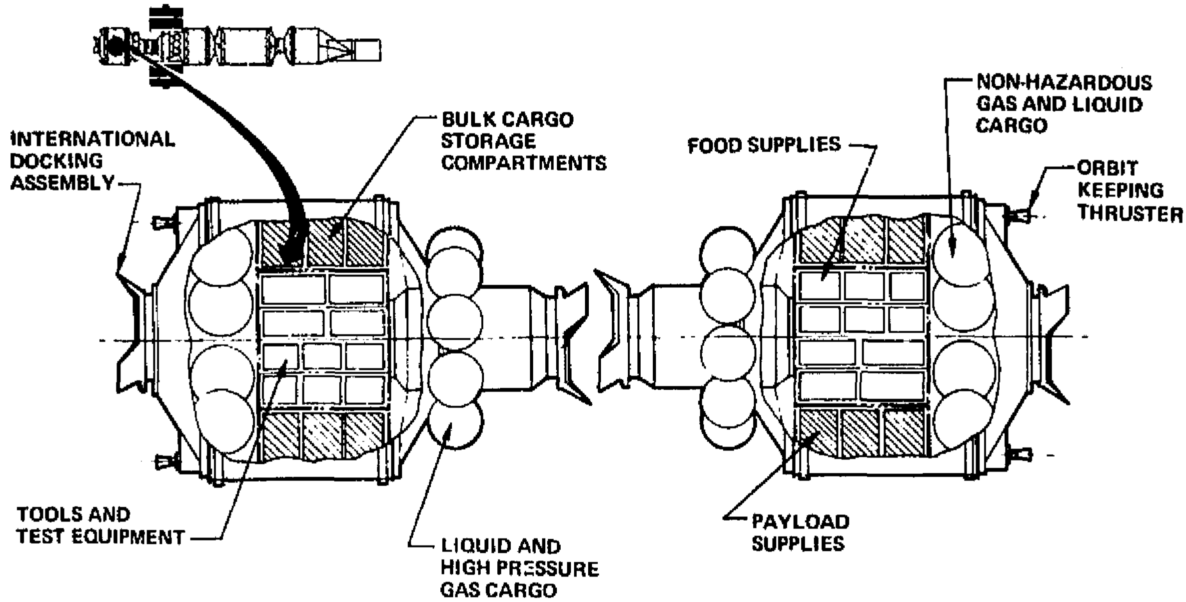

Figure 5-6. Baseline 4-Man MOSC Inboard Profile — Logistics Module

5.1.4.1 Structural/Mechanical Subsystem

The structural and mechanical subsystem includes the basic structure and all provisions for (1) structural accommodation of a four-man crew, (2) vehicle subsystems, and (3) MOSC payloads.

The mechanical equipment includes that required for (1) docking the core vehicle with payloads and logistics modules, (2) vehicle access, including hatches, airlocks, and viewports, (3) antenna deployment and solar array drive, (4) cargo handling and transfer, and (5) extravehicular activity support.

This subsystem is illustrated in the assembly-level breakdown in Figure 5-7.

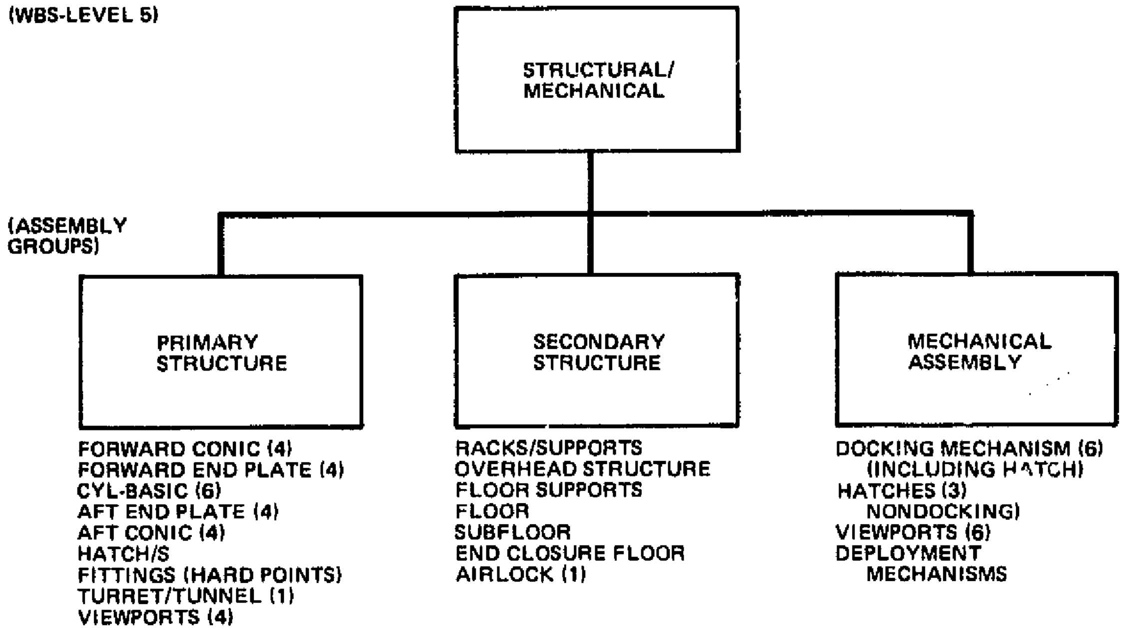

Figure 5-7. Structural/Mechanical Subsystem Assembly Breakdown

5.1.4.2 Environmental Control and Life Support Subsystem

The major portion of this subsystem, including the main control and active components, is located in the core vehicle. From this central location, the vehicle is conditioned with longitudinal ducting leading to the logistics and payload modules. Equipment cooling loops are integrated into the main thermal conditioning subsystem. Heat rejection is handled through space radiators mounted on the full cylindrical surface of the core vehicle. Water management utilizes a full water recovery approach.

This subsystem is illustrated to the assembly level in Figure 5-8.

(WBS-LEVEL 5)

ENVIRONMENTAL CONTROL AND LIFE SUPPORT

(ASSEMBLY GROUPS)

ATMOSPHERE SUPPLY AND CONTROL
- O_2 GAS STORAGE
- N_2 GAS STORAGE
- PORTABLE LIFE SUPPORT SYSTEM RECHARGE
- UMBILICAL LIFE SUPPORT
- PORTABLE O_2 BOTTLES
- REPRESS O_2 AND N_2 BOTTLES
- CABIN DUMP AND RELIEF
- PUMP DOWN ACCUM
- PRESSURE CONTROL
- PRESSURE REGULATOR (N_2 AND O_2)
- FANS
- DUCTING AND PLUMBING
- 96-HOUR PALLETS (INERTS)

ATMOSPHERE RECONDITIONING
- HUMIDITY CONTROL
- CO_2 REMOVAL
- VENTILATION
- TRACE CONTAM MONITORING
- AIR TEMPERATURE CONTROL
- ATMOSPHERE DISTRIBUTION
- AIRLOCK PRESSURE CONTROL
- CATALYTIC BURNER

FIRE CONTROL
- FIRE DETECTION
- SMOKE DETECTION
- FIRE SUPPRESSION

RADIATOR THERMAL CONTROL
- RADIATOR RECIRCULATION
- RADIATOR CONTROL ASSEMBLY
- INTERLOOP HEAT EXCHANGERS (2)
- THERMAL CAPACITORS
- REGENERATIVE HEAT EXCHANGER

EQUIPMENT THERMAL CONTROL
- COLD PLATES
- AVIONICS FAN
- PLUMBING
- HEAT EXCHANGER

WATER MANAGEMENT
- URINE WATER RECOVERY
- WASH WATER CONDENSATE RECOVERY
- RECOVERED WATER STORAGE
- CONTINGENCY WATER STORAGE

Figure 5-8. Environmental Control and Life Support Subsystem Assembly Breakdown

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5.1.4.3 Crew Accommodations

The crew accommodations subsystem provides facilities and equipment for the crew housing and living. It includes the equipment and facilities for recreation, exercise, lighting, dining, hygiene, medical care, food, food storage, safety, crew living and sleeping quarters, and space suits.

The assembly-level breakdown for this subsystem is illustrated in Figure 5-9.

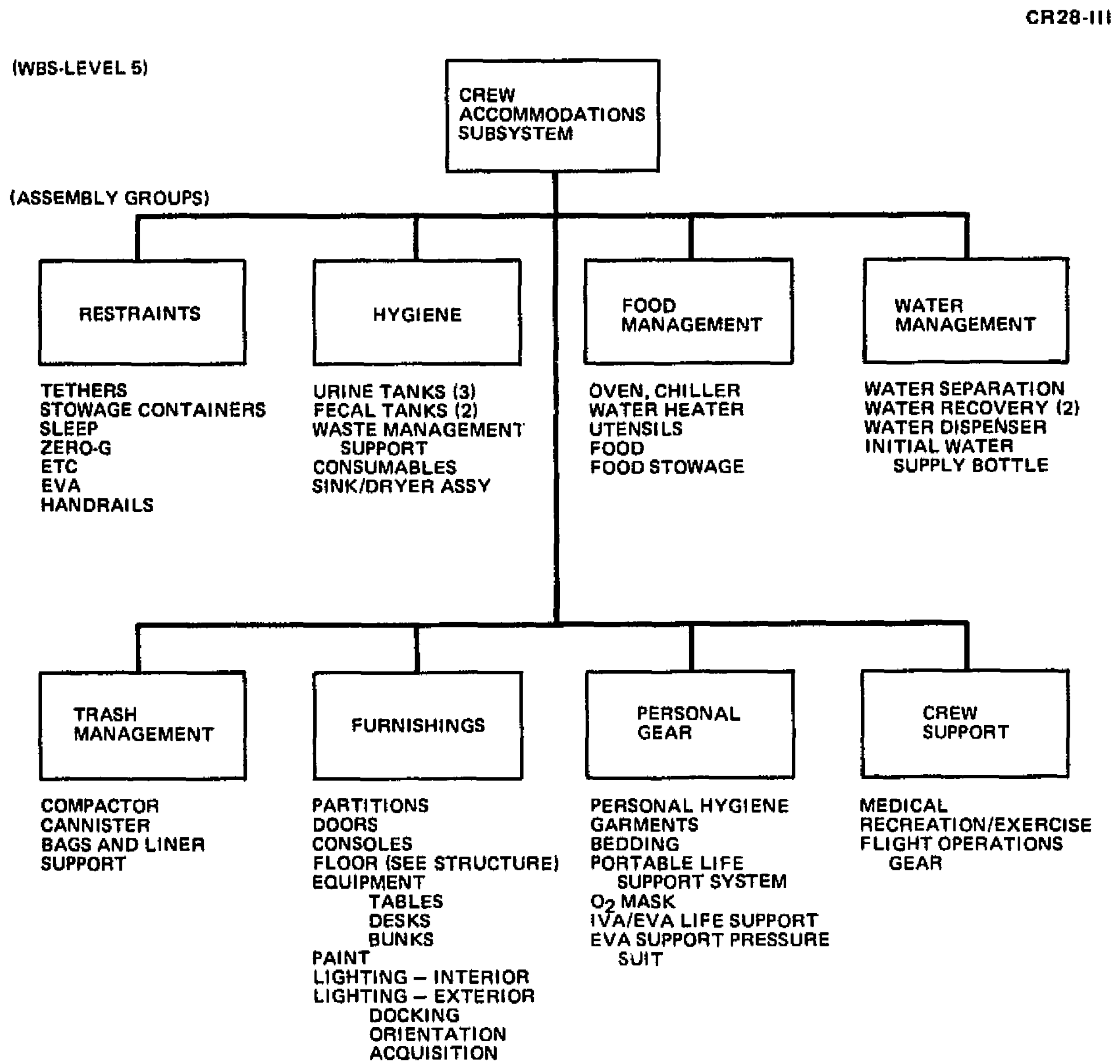

Figure 5-9. Crew Accommodations Subsystem Assembly Breakdown

5.1.4.4 Electrical Power Subsystem

The electrical power subsystem is a solar array power source, using deployment and orientation mechanisms to provide a universal orientation capability for the MOSC vehicle without interruption of power generation.

Storage batteries provide both the primary emergency power and the orbital eclipse power. Energy management equipment, storage and regulation equipment, power conditioning equipment and power distribution protection, switching assemblies, and internal/external lighting comprise the basic elements.

This subsystem is illustrated in the assembly-level breakdown in Figure 5-10.

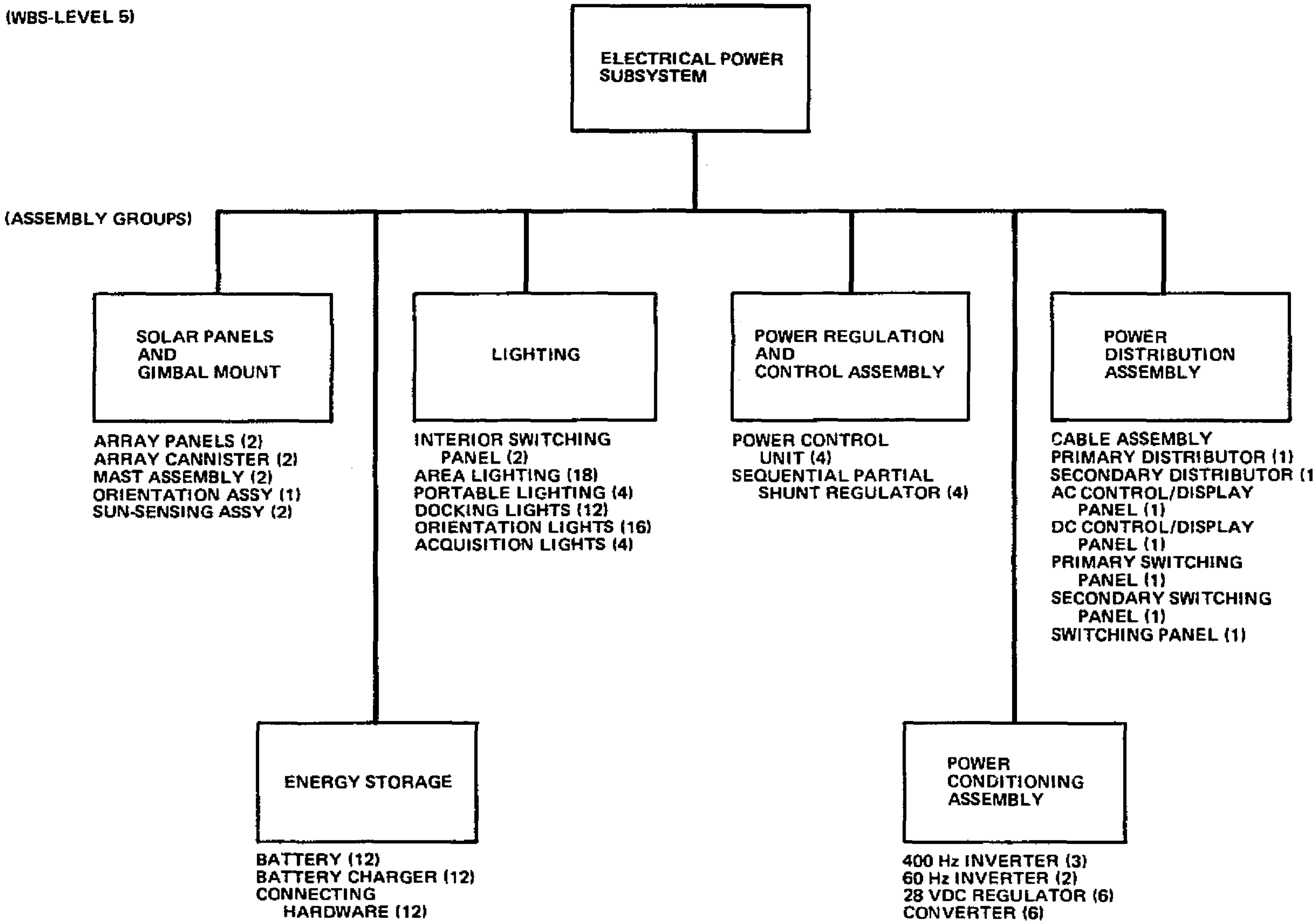

Figure 5-10. Electrical Power Subsystem Assembly Breakdown

5.1.4.5 Communications Subsystem

The communications subsystem provides:

1. MOSC-to-ground communications
2. MOSC-to-Shuttle communications
3. Module-to-module internal communications

It consists of antennas, amplifiers, receivers, transmitters with appropriate switching and multiplexing units, TV cameras, audio control, etc. This subsystem is illustrated in the assembly-level breakdown in Figure 5-11.

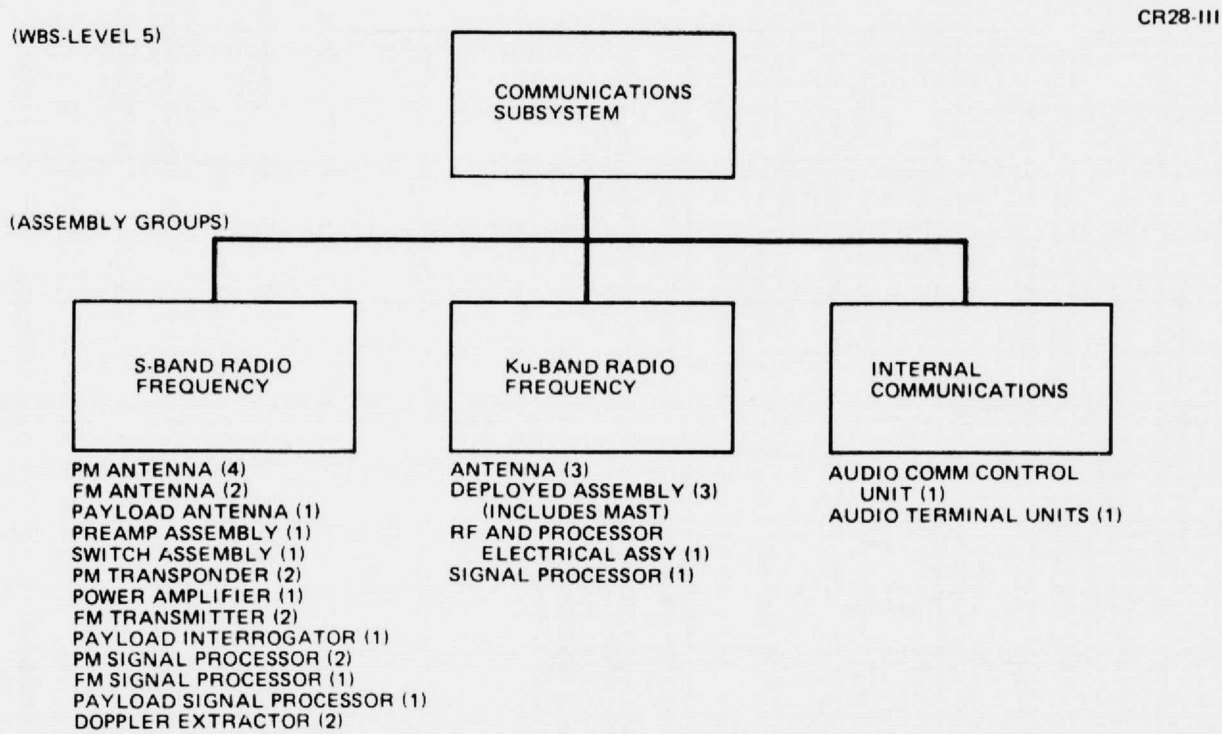

Figure 5-11. Communications Subsystem Assembly Breakdown

5.1.4.6 Data Management Subsystem

The data management subsystem consists of all the necessary equipment to transfer, store, and process data to and from payloads and subsystems. The subsystem is divided into two independent units in order to meet the requirements of payloads with their attendant data levels and types and the vehicle subsystems control with the requirement of continuous, autonomous control.

This subsystem is illustrated in the assembly-level breakdown in Figure 5-12.

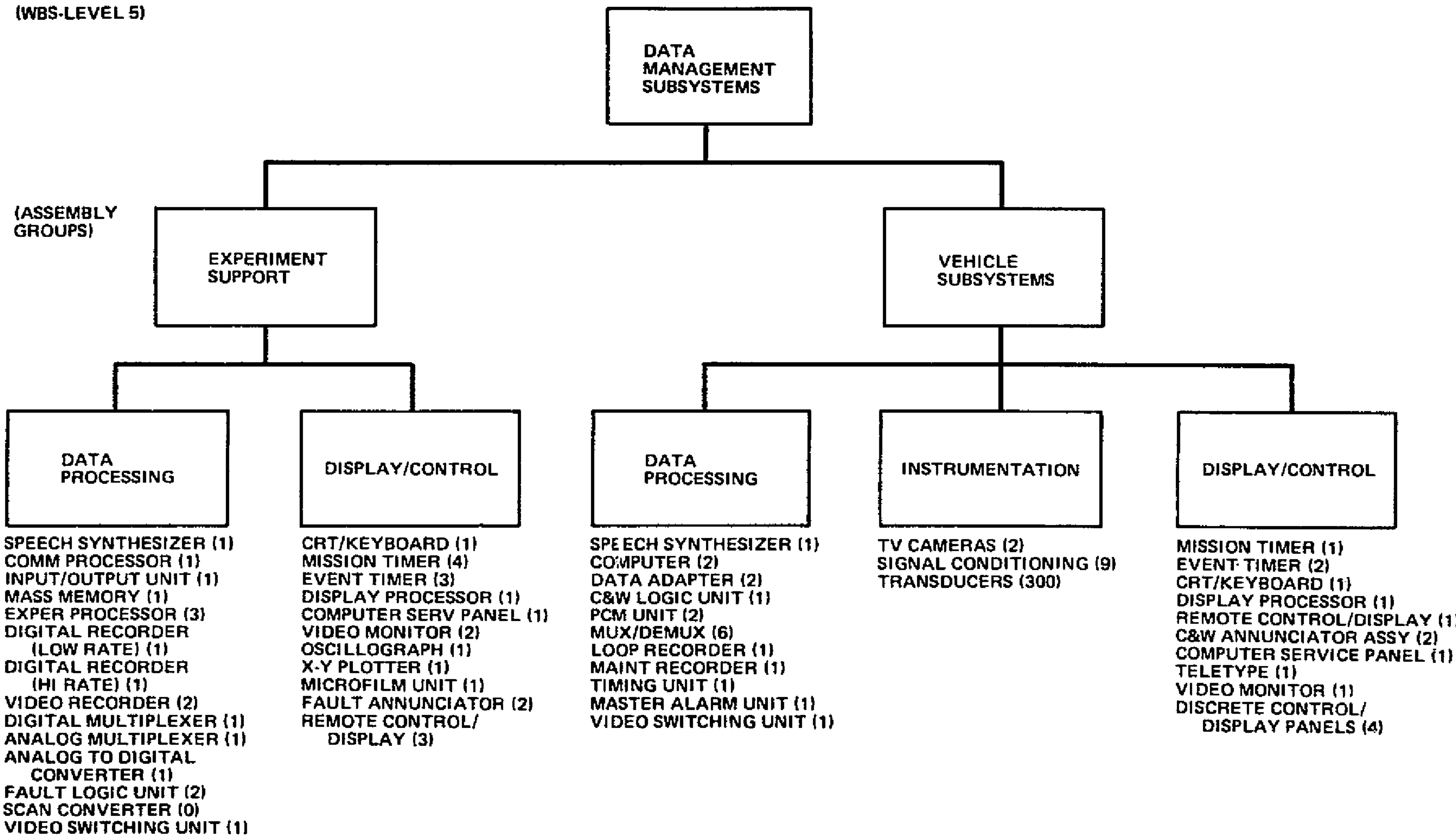

Figure 5-12. Data Management Subsystem Assembly Breakdown

5.1.4.7 Stabilization and Control Subsystem

The stabilization and control subsystem provides station navigational information to be used by experiments, Orbiter, payload modules, etc., and generates guidance commands for MOSC orbit keeping and maneuvers. The stabilization and control equipment consists of position and velocity sensors, electronics for sensors, computer interfaces, and display and control elements.

This subsystem is illustrated in the assembly-level breakdown in Figure 5-13.

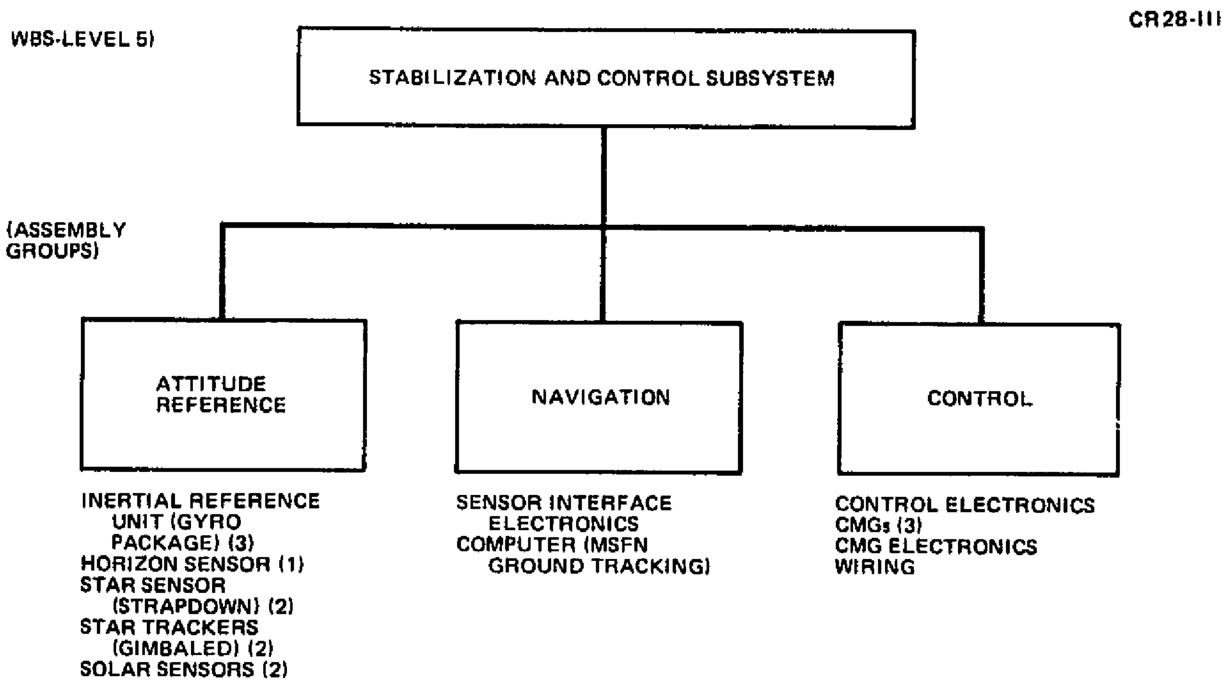

Figure 5-13. Stabilization and Control Subsystem Assembly Breakdown

5.1.4.8 Propulsion/Reaction Control Subsystem

This subsystem provides the thrust/impulse required to compensate for incomplete (missed) Orbiter docking attempts by controlling the resulting space station pitch and yaw rates within specified limits. The subsystem also provides the orbit keeping and backup attitude control.

The MOSC subsystem is a cold gas (N_2) subsystem which can be resupplied with GN_2 in orbit.

This subsystem is illustrated in the assembly-level breakdown in Figure 5-14.

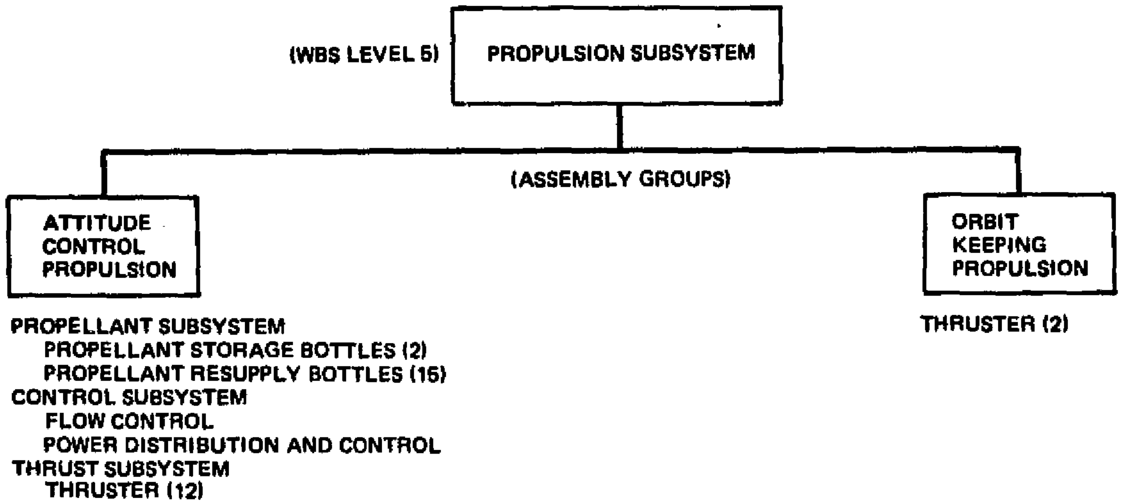

Figure 5-14. Propulsion Subsystem Assembly Breakdown

5.1.4.9 Environmental Protection Subsystem

This subsystem provides the passive protection for the crew against space environmental hazards of 1) thermal conditions which must be controlled to permit normal daily operations and 2) meteroid penetration of the pressure shell which must be prevented to assure long-duration mission safety.

This subsystem is shown in the assembly-level breakdown in Figure 5-15.

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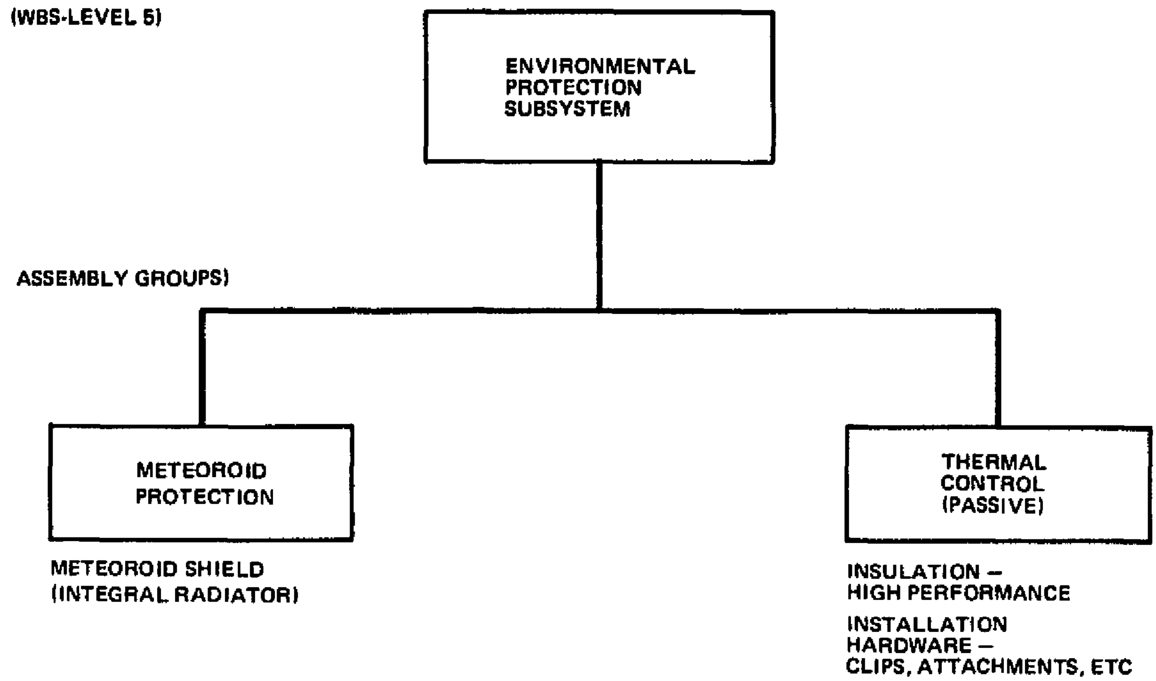

Figure 5-15. Environmental Protection Subsystem Assembly Breakdown

5.1.5 Mass Characteristics

The MOSC vehicle and subsystem weights were developed by analyzing system elements to the component level. Sufficient depth was generated in the conceptual designs on requirements and definition to support this approach when supplemented with data from earlier manned space flight programs. The subsystem weights were reviewed for their relative definition level, complexity, and historical growth and a varying contingency weight value was applied. The MOSC launch elements have, in all cases, at least a 10-percent contingency allowance. Actual weights were used for those components or structural elements selected from available hardware. By applying a minimum contingency of 10 percent, coupled with the use of existing spacecraft hardware data, it is believed that the resulting weight values are realistic even at this initial study period. The major weight reference sources were: Shuttle, Skylab, Spacelab, Apollo-Soyuz, plus the Boeing SEPS study and the MDAC Modular Space Station Phase B Study. Weight summary ground rules are shown in Table 5-3.

Table 5-3

WEIGHT SUMMARY GROUND RULES

1. Subsystems and consumables required for unmanned MOSC operation prior to first crew entry — approximately 7 days, plus first 7 days of manned operations and 4 days emergency stores.*

2. Logistics option — consumables and components which could be shifted to the logistics module of the second launch to increase the discretionary payload of the initial launch or accommodate increased subsystem weights.

3. Normal mission planning would assign the options to the first launch and maximize the discretionary payload of the second launch to accommodate experiment equipment/supplies.

4. Payload module weight does not include experiment equipment/supplies — does include the module floor and lights, power and ventilation provisions.

*The emergency stores must match the Shuttle turnaround time for emergency rescue, recent information indicates that 160 hours may be required for the emergency turnaround.

The mission mass summary for the Baseline 4-Man MOSC configurations is presented in Table 5-4.

The Baseline 4-Man MOSC first launch includes the core vehicle (i.e., the subsystem and habitability modules) for a total launch mass of 32,481 lbm (14,734 kg), if all consumables for the initial buildup period and the 90-day operational period are included.

Table 5-5 is the detail mass summary of the baseline 4-man MOSC vehicle. WBS identification is given to enable association with the costing information (Book 4).

Table 5-4

BASELINE 4-MAN MOSC MASS SUMMARY

Subsystem/Consumables Description	Mass (lb) [kg]			
	First Launch – Core Vehicle		Second Launch – 90-Day Logistic	
	Subsystem Module	Habitability Module	Logistic Module	Payload Module
Structure/Mechanical	4,279	5,496	4,977	4,762
Environmental Protection	323	575	195	489
Electrical Power	4,465	1,380	30	30
Propulsion	169	103	1,190	–
Data Management	1,532	1,344	212	443
Communication	323	821	86	14
Stability and Control	2,146	–	–	–
Environmental Control and Life Support	1,340	739	3,222	137
Crew Accommodations	816	2,194	2,391	169
Subtotal	15,393	12,652	12,303	6,044
Contingency	1,785	1,423	1,764	604
Inert Mass	17,178	14,075	14,067	6,648
Residuals/Reserves	144	816	999	227
Inflight Losses	268	–	1,458	–
Module Total	17,590 [7,979]	14,891 [6,795]	16,524 [7,495]	6,875 [3,119]
Launch – Nominal	32,481 [14,734]		23,399 [10,614]	
Docking Module	2,200 [998]		2,200 [998]	
Crew/Equipment	–		1,500 [680]	
Launch – Total	34,681 [15,728]		27,099 [12,289]	
Discretionary Payload	–		6,359 [2,884]*	
Landing – Total	34,413 [15,606]*		32,000 [14,512]*	

*Inflight losses jettisoned

Table 5-5

MOSC FOUR MAN DETAIL MASS SUMMARY 90-DAY LOGISTIC CYCLE

WBS		Subsystem Module (SM)	SM Logistic Options	Habitable Module (HM)	HM Logistic Options
03-02	Structure/Mechanical	(4279)	( )	(5496)	( )
	Primary Structure	2886	----	2935	----
	Fwd Conic	467		467	
	Fwd End Plate	134		----	
	Cly-Basic	732		1464	
	Aft End Plate	134		134	
	Aft Conic	494		494	
	Hatch/s	172		258	
	Fittings (Hard Points)	100		118	
	Turret/Tunnel	653		----	
	Secondary Structure	480	----	1648	----
	Racks/Supports	99		199	
	Overhead Structure	77		154	
	Floor Supports	86		172	
	Floor	218		436	
	Subfloor	----		----	
	End Closure Floor	----		----	
	Airlock	----		687	
	Docking	913	----	913	----
03-10	Environmental Control	(323)	( )	(575)	( )
	HPI	195		319	
	Rack Insulation	----		----	
	Radiator/Meteoroid	128		256	
03-05	Electrical Power	(3625)	(840)	(540)	(840)
	Solar Panels & Gimbal Mount	2375	----	----	
	Batteries	420	840	420	840
	Power Regulation & Control	300	----	----	----
	Power Conditioning	470	----	90	----
	Power Distribution	60	----	30	----
03-09	Propulsion	(169)	( )	(103)	( )
	N_2 Tanks	156		----	
	Thrustor Modules	----		90	
	Distribution/Controls	13		13	
03-07	Data Management	(1532)	( )	(1344)	( )
	Subsystem	1326		258	----
	Data Processing	558		60	----
	Instrumentation	262		132	----
	Display & Controls	506		66	----
	Experiment	----		766	----
	Data Processing	----		476	----
	Display & Controls	----		290	----
	Wiring	206		320	----

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Table 5-5

JR-MAN DETAIL MASS SUMMARY 90-DAY LOGISTIC CYCLE

gistic Options	Habitable Module (HM)	HM Logistic Options	Logistic Module	LM Cargo	Payload Module
	(5496)	( )	(4977)	( )	(4762)
---	2935	----	2571	----	2251
	467		467		467
	----		134		134
	1464		732		732
	134		134		134
	494		494		494
	258		172		172
	118		218		118
	----		220		----
---	1648	----	580	----	685
	199		199		----
	154		77		77
	172		86		172
	436		218		436
	----		----		----
	----		----		----
	687		----		----
---	913	----	1826	----	1826
	(575)	( )	(195)	( )	(489)
	319		195		319
	----		----		----
	256		----		170
	(540)	(840)	(30)	( )	(30)
---	----		----	----	----
840	420	840	----	----	----
---	----	----	----	----	----
---	90	----	----	----	----
---	30	----	30	----	30
	(103)	( )	(20)	(1170)	( )
	----		----	1170	
	90		----	----	
	13		20	----	
	(1344)	( )	(212)	( )	(443)
	258	----	132		----
	60	----	----		----
	132	----	132		----
	66	----	----		----
	766	----	----		303
	476	----	----		30
	290	----	----		273
	320	----	80		140

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WBS		Subsystem Module (SM)	SM Logistic Options	Habitable Module (HM)	HM Logistic Options
03-06	Communication	(323)	( )	(821)	( )
	S-Band	274		60	
	Antennas	22		----	
	RF & Signal Processor	252		60	
	Ku-Band	----		685	
	Antennas (Hi-Gain)	----		525	
	RF & Processor	----		160	
	Internal Communication	9		16	
	Wiring	40		60	
03-08	Stabilization & Control	(196)	(1950)	( )	( )
	CMGs (3)	----	1950	----	
	Horizon Sensor	45	----	----	----
	Solar Sensors (2)	10	----	----	----
	Star Sensors (2)	120	----	----	----
	Rate Gyros (3)	5	----	----	----
	Wiring	16	----	----	----
03-03	Environmental Control & Life Support	(1340)	( )	(739)	( )
	Equipment Thermal Control	192	----	91	----
	Cold Plates	118		17	
	Avionics Fan	16		16	
	Plumbing	10		10	
	Heat Exchanger	48		48	
	E.C. Personal	723	----	628	----
	Atmosphere Supply & Cont.	496		43	
	Repressurization O_2 & N_2 Bottles	405		----	
	O_2 & N_2 Storage Bottles	----		----	
	Cabin Dump & Relief	7		7	
	Pump Down Accumulator	----		----	
	Pressure Control	28		----	
	Pressure Regulator (N_2 & O_2)	20		----	
	PLSS Recharge	----		----	
	Fans	36		36	
	Atmosphere Reconditioner	148		42	
	Air Temp. & Humid. Cont.	35		35	
	Contaminant Control	33		----	
	CO_2 Removal	----		----	
	Airlock Pressure Control	----		7	
	Catalytic Burner	80		----	
	Fire Control	32		32	
	Fire & Smoke Detection	12		12	
	Fire Suppression	20		20	
	Ducting & Plumbing	47		50	
	96-Hour Pallets (Inerts)	----		461	
	Radiator Thermal Control	425	----	20	----
	Radiator Recirculation	20		20	
	Radiator Control Assy	40		----	
	Interloop Heat Exchangers (2)	60		----	
	Thermal Capacitors	275		----	
	Regenerative Heat Exchanger	30		----	

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ogistic Options	Logistic Module	LM Cargo	Payload Module
	(86)	( )	(14)
	52		----
	22		----
	30		
	----		----
	----		----
	----		----
	4		4
	30		10
	( )	( )	( )
	----		----
----	----		----
----	----		----
----	----		----
----	----		----
----	----		----
	(119)	(3103)	(137)
----	----	----	30
	----	----	----
	----	----	----
	----	----	----
	----	----	----
----	119	3103	107
	47	2025	7
	----	----	----
	----	2025	----
	7	----	7
	----	----	----
	----	----	----
	40	----	----
	----	----	----
	----	----	----
	----	1078	35
	----	----	35
	----	----	----
	----	1078	----
	----	----	----
	----	----	----
	32	----	32
	12		12
	20		20
	40	----	33
	----	----	----
----	----	----	----
	----		----
	----		----
	----		----
	----		----
	----		----

Table 5-5 (Continued)

WBS		Subsystem Module (SM)	SM Logistic Options	Habitable Module (HM)	HM Logistic Options
03-04	Crew Accommodations	(683)	(133)	(617)	(1577)
	Restraints	20	68	30	138
	Tethers	----	68	----	138
	Stowage Containers				
	Sleep				
	Zero-G				
	ETC				
	EVA				
	Handrails	20	----	30	----
	Crew Life Support	414	65	186	141
	Hygiene	143	65	----	----
	Urine Tanks (3)	----	39	----	----
	Fecal Tanks (2)	----	26	----	----
	Waste Management Supt.	123	----	----	----
	Consumables	----	----	----	----
	Sink/Dryer Assy	20	----	----	----
	Food Management	----	----	161	121
	Oven, Chiller	----		----	----
	Water Heater	----		161	----
	Utensils	----		----	----
	Food	----		----	9
	Food Stowage	----		----	2
	Housekeeping (see Hygiene)	----	----	----	----
	Trash Management	----	----	10	----
	Compactor	----		----	----
	Cannister	----		----	----
	Bags & Liner	----		----	----
	Support	----		10	----
	Water Management	271	----	15	20 ----
	Water Separation	11		----	----
	Water Recovery (2)	260		----	----
	Water Dispenser	----		15	----
	Initial Water Supply Bottle	----		----	2
	Cargo Handling	10	----	10	----
	Furnishings	239	----	391	----
	Partitions	77		154	----
	Doors	6		18	
	Consoles	----		----	
	Floor (see Structure)	----		----	
	Equipment	16		80	
	Tables	----		17	
	Desks	16		48	
	Bunks	----		15	
	Paint	10		17	
	Lighting - Interior	10		30	
	Lighting - Exterior	120		92	
	Docking	80		32	
	Orientation	20		20	
	Acquisition	20		40	
	Personal Gear	----	----	----	560
	Personal Hygiene				12
	Garments				136
	Bedding				----
	Miscellaneous				412
	Portable Life Supt. Sys.				41
	O_2 Mask				---
	IVA/EVA Life Support				---
	IVA Support				---
	Pressure Suit				---

Table 5-5 (Continued)

	Habitable Module (HM)	HM Logistic Options	Logistic Module	LM Cargo	Payload Module
	(617)	(1577)	(152)	(2239)	(169)
	30	138	20	----	20
	----	138	----		----
	30	----	20		20
	186	141	----	2239	----
	----	----	----	398	----
39	----	----	----	78	
26	----	----	----	26	
--	----	----	----	----	
--	----	----	----	294	
--	----	----	----	----	
	161	121	----	1664	----
	----	----	----	----	
	161	----	----	----	
	----	----	----	182	
	----	96	----	1235	
	----	25	----	247	
	----	----	----	----	----
	10	----	----	146	----
	----	----	----	80	
	----	----	----	60	
	----	----	----	6	
	10	----	----	----	
	15	20 ----	----	31	----
	----	----	----	----	
	----	----	----	31	
	15	----	----	----	
	----	20	----	----	
	10	----	20	----	10
	391	----	112	----	139
	154	----	----		
	18		----		
	----		----		
	----		----		
	80		----		
	17				
	48				
	15				
	17		10		
	30		10		
	92		92		
	32		32		
	20		20		
	40		40		
	----	560	----	----	----
		12			
		136			

		412			
		412			

Table 5-5 (Continued)

WBS		Subsystem Module (SM)	SM Logistic Options	Habitable Module (HM)	HM Logistic Options
03-04 (cont)	Crew Accommodations (Cont)				
	Crew Support	----	----	----	738
	Medical				100
	Recreation/Exercise				190
	Flight Ops Gear				448
	Subtotaled Mass (LBM)	[12470]	[2923]	[10235]	[2417]
00-00	Contingency	(1284)	(501)	(1024)	(399)
	Structure/Mechanical	24	----	82	----
	Environmental Protection	65	----	115	----
	Electrical Power	363	84	54	84
	Propulsion	17	----	10	----
	Data Management	306	----	269	----
	Communication	65	----	164	----
	Guidance & Control	39	390	----	----
	Environmental Control & Life Supt.	268	----	134	----
	Crew Accommodations	137	27	123	315
	Misc	----	----	73	----
	Inert Mass (LBM)	[13754]	[3424]	[11259]	[2816]
	Residuals/Reserves	(144)	( )	(756)	(60)
	Atmosphere	110	----	184	----
	Propellant Trapped	5	----	----	----
	Radiator	22	----	43	----
	Cold Plates	7	----	2	----
	Water	----	----	----	60
	96 Hour Pallet	----	----	527	----
	Metabolic O_2	----		141	
	Water	----		386	
	Metabolic O_2				
	Inflight Losses	(268)	( )	( )	( )
	Leakage	18			
	Repressurization	200			
	Propellant	50			
	Total Mass (LBM)	[14166]	[3424]	[12015]	[2876]

FOLDOUT FRAME 1

tinued)

HM Logistic Options	Logistic Module	LM Cargo	Payload Module
738	....	....	....
100			
190			
448			
17]	[5791]	[6512]	[6044]
399)	(579)	(1185)	(604)
....	29	....	34
....	39	....	98
84	3	....	3
....	2	117	....
....	42	....	88
....	17	....	3
....	....	....	....
....	24	620	27
315	30	448	34
....	393	....	317
16]	[6370]	[7697]	[6648]
60)	(92)	(907)	(227)
....	92	....	184
....	....	101	....
....	....	....	43
....	....	....	....
60	....	....	....
....	....	....	....
		806	
)	( )	(1458)	( )
		450	
		....	
		1008	
76]	[6462]	[10062]	[6875]

FOLDOUT FRAME 2

The second launch would include the logistic module with all the normal logistic supplies necessary for the 90-day mission plus a payload module. The total launch mass is 23,399 lbm (10,514 kg) with approximately 6,359 lbm (2,884 kg) available for actual experiment equipment, based on a landing mass of 32,000 lbm (14,515 kg). The remaining 3,700 lbm (1,678 kg) is allocated to a transfer tunnel and the four crew members. Figure 5-16 illustrates the cargo bay installation and resulting launch and landing Orbiter X_o CG stations.

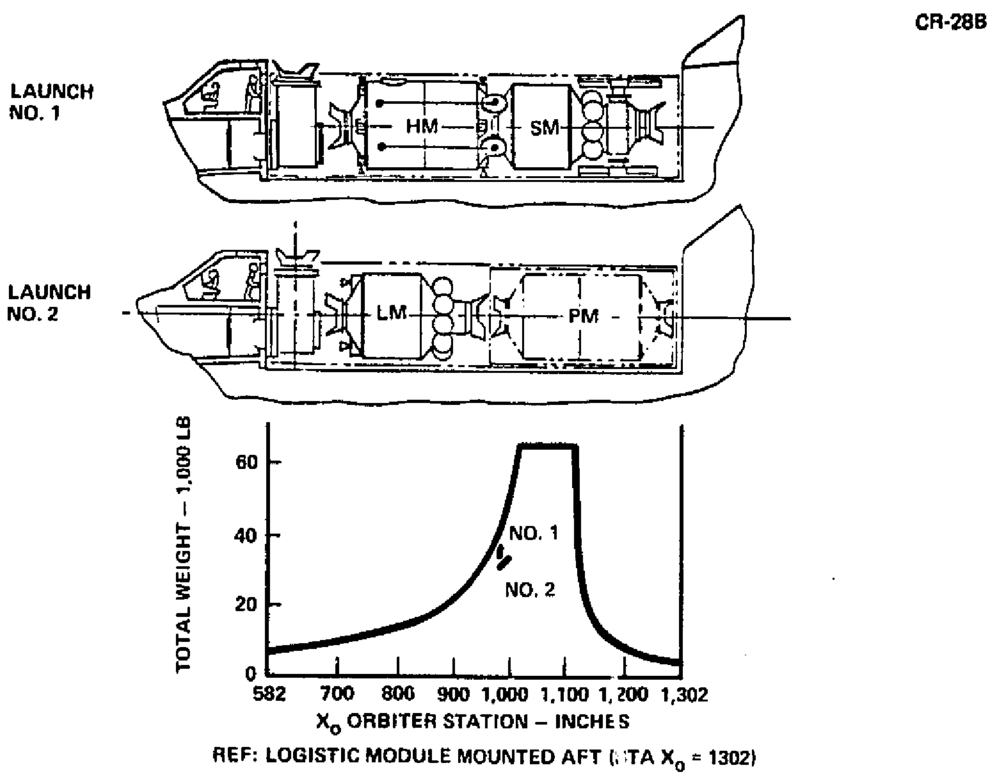

Figure 5-16. Baseline 4-Man MOSC Vehicle CG vs Orbiter Landing Envelope

The logistics options are summarized in Table 5-6 and noted by reference asterisks. These include those elements not required during the buildup phase. Some degree of moving mass not essential to a particular launch/mission operation to an alternate launch is possible. These data are tabulated under "Logistics Options" and could prove to be important if the launch or landing weight had to be reduced.

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Table 5-6

BASELINE 4-MAN MOSC MASS SUMMARY, WITH LOGISTICS OPTIONS

Subsystem/ Consumables Description	Mass (lb) [kg]						
	First Launch (core vehicle)				Second Launch (90-Day Logistic)		
	Subsystem Module		Habitability Module		Logistic Module		Payload Module
	Basic	Logistics* Options	Basic	Logistics* Options	Basic	Cargo	
Structure/Mechanical	4,279	—	5,496	—	4,977	—	4,762
Environmental Protection	323	—	575	—	195	—	489
Electrical Power	3,625	840	540	840	30	—	30
Propulsion	169	—	103	—	20	1,170	—
Data Management	1,532	—	1,344	—	212	—	443
Communication	323	—	739	—	86	—	14
Guidance and Control	196	1,950	—	—	—	—	—
Environmental Control and Life Support	1,340	—	691	—	119	3,103	137
Crew Accommodations	683	133	617	1,577	152	2,239	169
Subtotal	12,470 [5,657]	2,923 [1,326]	10,235 [4,643]	2,417 [1,096]	5,791 [2,627]	6,512 [2,954]	6,044 [2,742]
Contingency	1,284	501	1,024	399	579	1,185	604
Inert Mass	13,754 [6,239]	3,424 [1,553]	11,259 [5,107]	2,816 [1,277]	6,370 [2,889]	7,697 [3,491]	6,648 [3,016]
Residuals/Reserves	144	—	756	60	92	907	227
Inflight Losses	268	—	—	—	—	1,458	—
Total Mass	14,166 [6,426]	3,424 [1,553]*	12,015 [5 450]	2,876 [1,305]*	6,462 [2,889]	10,062 [4,564]	6,875 [3,119]
Module Total Mass (lb) [kg]	17,590 [7,979]		14,891 [6,796]		16,524 [7,495]		6.875 [3,119]
Total Launch Mass with Options	32,481 [14,734]				23,399 [10,614]		
Total Launch Mass without Options	26,181 [11,876]				29,699 [13,472]		

*Mass of items which can be shifted to an alternate

5.1.6 Shuttle Contamination Potential

The Shuttle Orbiter reaction control system (RCS) has the potential for being a major source of payload contaminants. Contamination of sensitive spacecraft surfaces by exhaust plume impingement from a rocket engine is of current concern in the design of the STS. Specifically, degradation in performance of thermal control coatings and optical systems such as lenses, view ports, reflective surfaces, and solar cells as a result of plume impingement abrasion or contaminant deposition can result in compromises of mission effectiveness.

The Shuttle RCS employs bipropellant thrusters using monomethylhydrazine (MMH) as the fuel and nitrogen tetroxide (N_2O_4) as the oxidizer. Two thruster sizes are used: (1) main RCS engine operating at a rated vacuum thrust of 900 lb (3,003 N) to provide attitude control and translational capability, and (2) vernier RCS operating at a rated vacuum thrust of 25 lb (111 N) to provide more precise attitude hold capability.

Plume contamination from a conventional bipropellant RCS engine, such as those to be used on the Orbiter, takes one or more of the following four forms: (1) reacted or unreacted propellant vapor; (2) incompletely burned droplets expelled through the throat; (3) unburned propellant that impinges upon the chamber wall and is eventually ejected from the nozzle lip; and (4) condensed combustion products. Condensed combustion products are usually present in negligible amounts for conventional liquid-fueled rocket engines.

The vapors of fuel, oxidizer, or combustion products emitted during preignition, ignition, steady-state, or post-cutoff dribble periods will form plumes that can impinge upon various surfaces with the possibility of deposition and in-situ reaction. Contamination from this source usually takes the form of a hazy deposit of smokelike particles (fairly uniform in size, 1 to 2 microns).

The fuel and oxidizer droplets, which are too large to burn completely in the chamber and which are centrally directed, will pass through the nozzle throat. These particles will be accelerated by aerodynamic forces both

upstream and downstream of the throat, and can attain quite high velocities, which gives this class of particles the capability of doing considerable damage by abrasion. Incompletely burned droplets are typically liquid when they pass through the throat, with temperatures not far from the temperature of the propellant in the tank. When the volatile droplets pass into the low-pressure regions of the plume, however, they vacuum-vaporize 10 to 20 percent of their mass quite rapidly (on the order of 3 milliseconds for a 100-micron droplet) and freeze into solid particles in distances ranging from a few inches to a few tens of feet, depending upon the particle size and physical properties (1.5 feet for a 100-micron fuel particle moving at 500 fps). The frozen particles eventually vaporize completely under the influence of solar radiation; however, this is a much slower process. At least 20 seconds are required to vaporize a frozen 100-micron fuel particle, which in this time travels some 10,000 feet to a point where it is no longer of importance as a contaminant source.

The third form of contamination is the propellant that impinges upon the chamber wall and is then dragged downstream under the influence of shear force from the combustion product gases. If this wall-film material is able to move to the nozzle lip without being thermally destroyed, it will be thrown off as large droplets in directions roughly normal to the axis of the chamber. This material is generally dark colored and shows the effects of thermal decomposition.

Finally, certain gaseous combustion products such as H_2O and CO_2 may condense into liquid or solid droplets during the rapid expansion process. For typical liquid bipropellant engines, however, rarefaction of the plume flow field in the region conducive to condensation usually produces a very small amount of condensed-phase combustion products; those that are produced are generally submicron in size.

There are 14 main engines located in the forward RCS modules and 24 in the OMS pods. Figure 5-17 shows the gas plume flow field and constituents of the combustion products for a main engine. The mass fraction, major constituents, sizes, and potential contamination are listed on the right of the figure. Figure 5-18 shows the thruster 95 percent streamline of the gaseous phase plume. Figure 5-19 shows the Orbiter RCS thrusters 95 percent streamline plume geometries.

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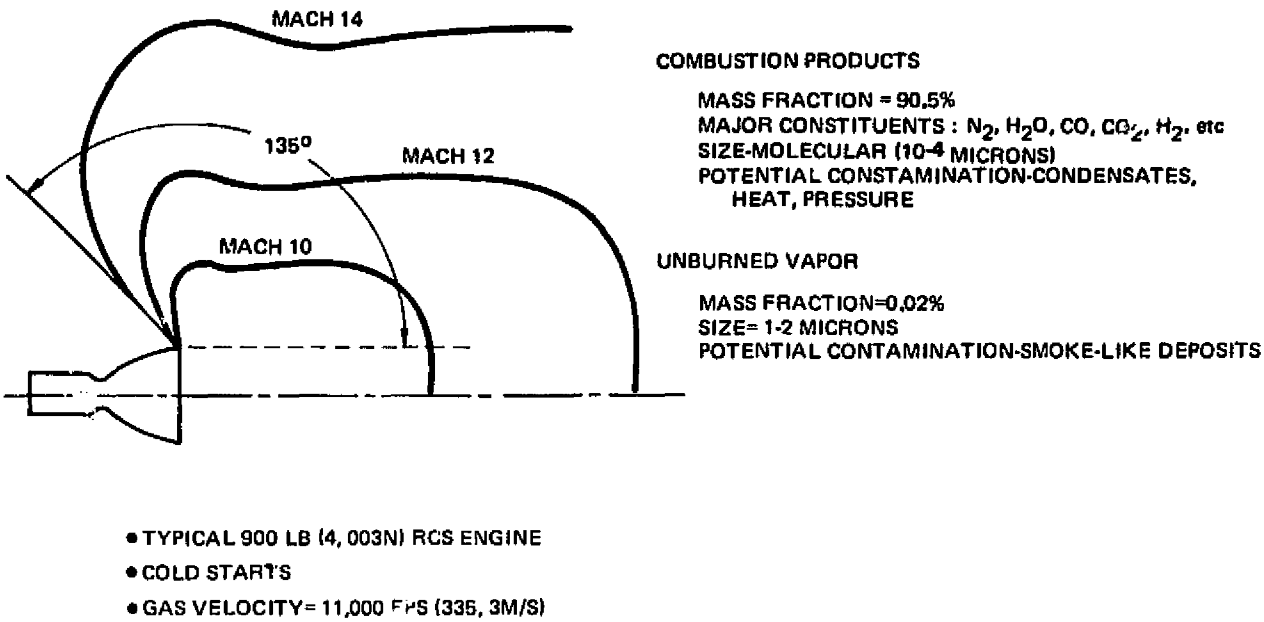

Figure 5-17. Orbiter RCS Gas Plume Flow Field and Constituents

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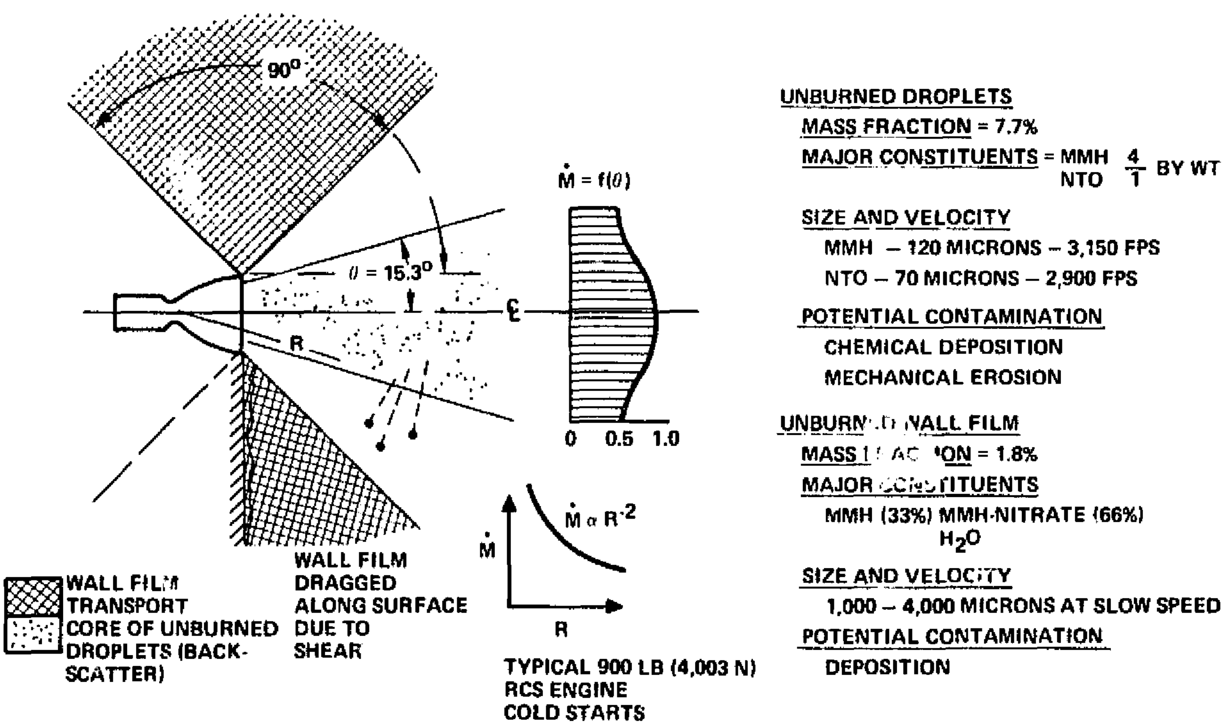

Figure 5-18. Orbiter RCS 95 Percent Steamline of the Gaseous Phase Plume

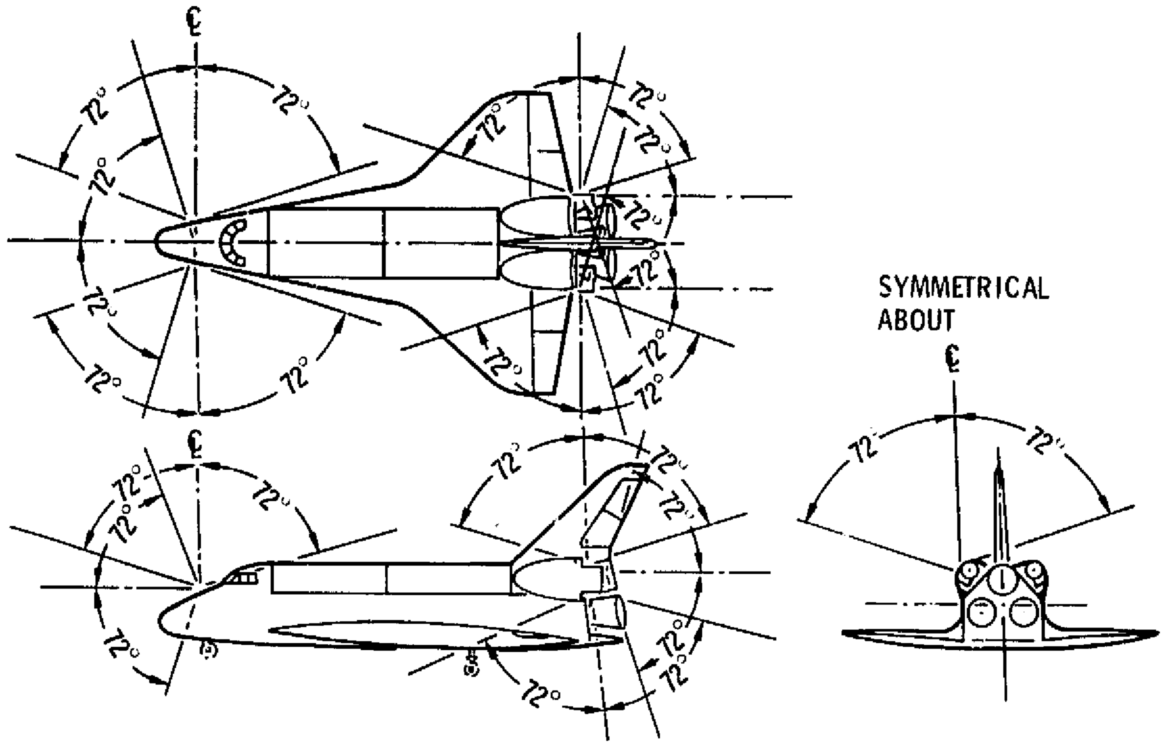

Figure 5-19. Orbiter RCS 95 Percent Gas Phase Plume Envelopes

The vernier RCS consists of six engines. Two are located in the forward RCS module adjacent to the main RCS thrusters (one on each side) and fire in the down (-z) direction. Four (two on each side) are located aft on the OMS pods. Two fire sideways, one in the +y and one in the -y direction; the other two fire in the downward (-z) direction. Figure 5-20 shows the Orbiter vernier thrusters 95 percent streamline plume geometries.

Of major concern are the upward-firing main RCS engines. As can be seen in Figure 5-21, the MOSC is well within the plume boundaries during docking operations. Rotating the solar panels to reduce the impingement area exposed to the forward plume maximizes the areas for the aft thruster and vice versa.

It may be necessary to retract the solar panels during docking operations. However, the extent of the contamination was not assessed beyond recognizing that a potential problem exists. It is recommended that this be the subject of further study in future efforts.

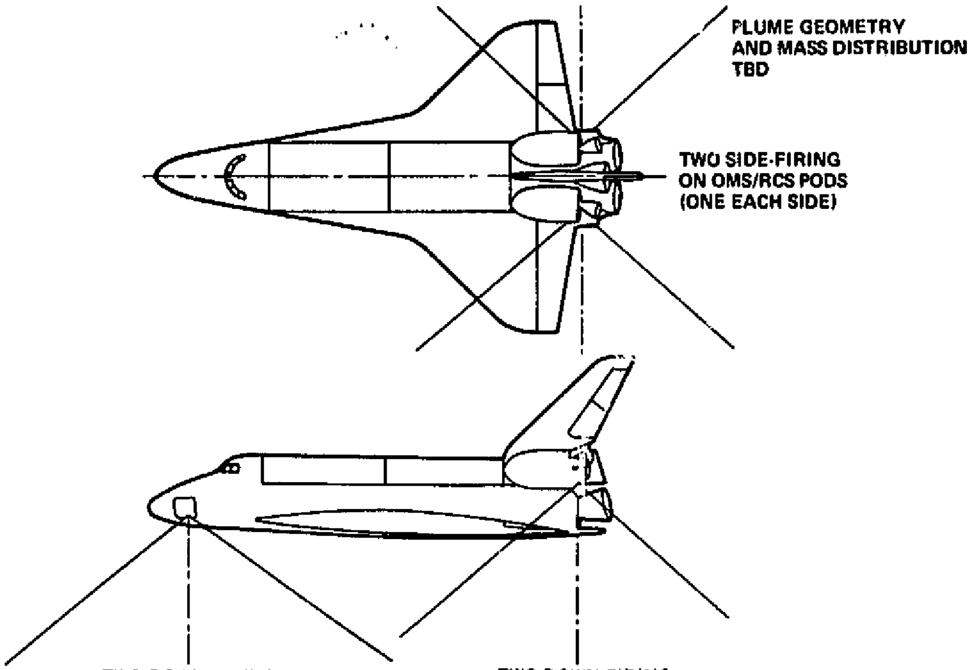

Figure 5-20. Orbiter Vernier RCS 95 Percent Gas Phase Plume Envelopes

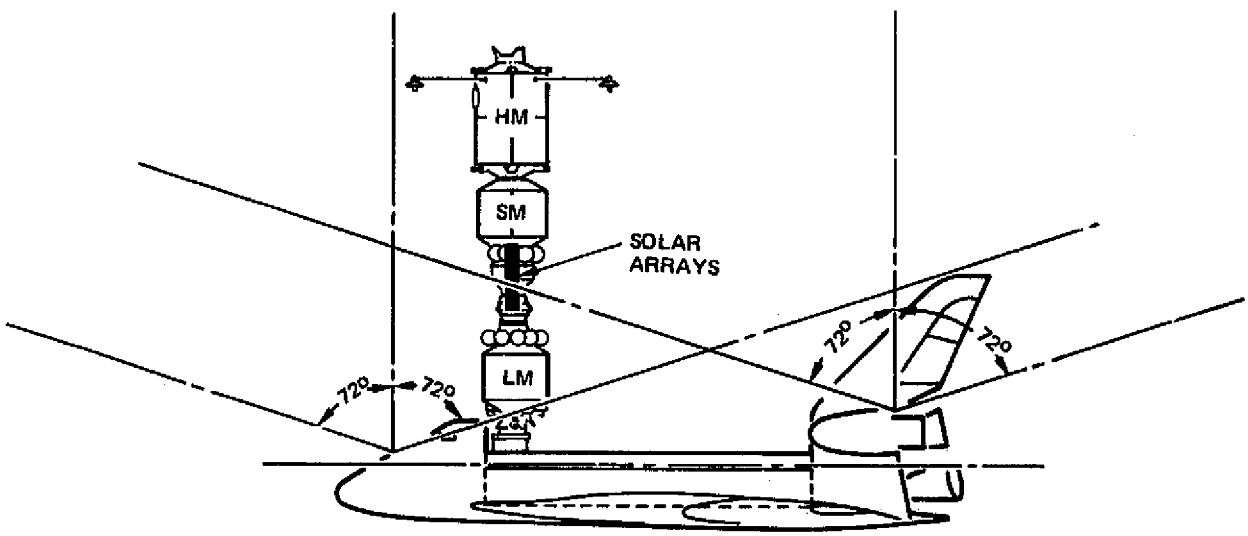

Figure 5-21. Relationship of MOSC to Orbiter RCS Plumes During Docking Operations

L. 2

5.1.7 Vehicle Characteristics and Accommodations Summary

The information contained in Table 5-7 summarizes the payload support and accommodations. It also includes top-level subsystem performance data.

The preceding conceptual drawings in conjunction with these performance data establishes the baseline for the definition of alternative configuration to the Baseline 4-Man MOSC.

5.2 SUBSYSTEMS ANALYSIS

The study approach to the development of sound MOSC configurations stressed the study guidelines of low cost and utilization of available technology and hardware. The baseline configuration derived in the study was based on the analyses conducted in Task 2 – Subsystem Tradeoffs and Task 3 – Subsystem Concept Selection. The results of this task work are summarized in this section. A significant study result based on the study guideline of maximum utilization of available hardware and technology was that approximately 75 percent of the components selected were in that category.

The mission requirements and vehicle characteristics that were used for defining the subsystems are presented in Table 5-8. Subsystems selected from available hardware/technology are summarized in Table 5-9. The primary thrust of these analyses was the preliminary definition of subsystems to the level required for development and selection of the MOSC configurations and for the programmatic analyses reported in Book IV. Subsystem trades were based on operation of the MOSC facility in low Earth orbit only.

5.2.1 Structural/Mechanical

The conceptual design in this technical area was directed toward the primary structure, vehicle structural configuration, and general internal arrangement of modules and subsystems. In consonance with the minimum-cost groundrule, available hardware was selected for each possible major element. However, detail design analyses must be conducted to verify the structural design and identify any modifications peculiar to the MOSC vehicle.

5.2.1.1 Primary Structure

The two major elements in this category are (1) the pressure shell for the manned modules and (2) the unpressurized pallets for mounted external scientific equipment.

Table 5-7

MOSC 4-MAN BASELINE PAYLOAD ACCOMMODATION AND MISSION CHARACTERISTICS SUMMARY

Mission/Vehicle Parameters

- Vehicle Orbital Life - 5 years
- Crew Exchange Period - 90 days
- Resupply Period - 90 days
- Number of Crew - 4
- Number of Manned Modules - 3 basic plus payload modules
- Number of Unmanned Pallets - one to three
- Orbital Altitude - 200 nmi nominal (100 to 300 nmi range)
- Orbital Inclination - 28.5 and 90° (One facility in each orbit)
- Vehicle Orientation - All axes (universal solar array pointing)
- Launch Weight - 65K lb
- Planned Landing Weight - 32K lb

Subsystem/Payload Accommodation Characteristics

- ECLS
  - Open loop atmosphere (1 ATM-air) with LI OH or CO_2 removal
  - Closed loop water with vapor compression
- Electrical Power - flexible foldout solar arrays (SEPS)
  - 25 kW at 50°C
  - 36 kWh batteries (12 batteries)
  - 4.0 kW for subsystems
  - 8.5 kW for payloads
- Communications
  - Audio and subsystem data, tracking - S-band. Data rates: 72,216 kbps receive; 192, 240, 576 kbps transmit
  - Wide band scientific digital data, television - K-band. Data rates: 2-4.5 MHz; 50 mbps transmit
  - Research Satellite Communications 20 Channels S-band. Data rates/channel: 32 kbps voice, 6.4 kbps command transmit; 16 kbps data; 32 kbps voice receive
- Data Management
  - Subsystem data processing - Orbiter equipment - centralized
  - Experiment data processing - Distributed equipment (1 mbps Serial data - 40K word memory)
- Stability and Control
  - Angular momentum capacity - 3 CMG's
    - 2 active (18,000 ft lb-sec capacity each)
    - 1 reserve
  - Universal orientation to one arc sec accuracy (0.1 arc sec/sec stability)
    - Solar inertial
    - Local vertical
    - Stellar orientation
- Reaction Control and Propulsion
  - Cold gas - N_2
  - Total impulse - 60K lb-sec
    - 80 percent orbit-keeping
    - 20 percent reaction control
  - Thrusters - 14 at 200 lb each

Table 5-8

BASELINE REQUIREMENTS

I. MISSION DESCRIPTION	
• Vehicle Life	5 years or more
• Emergency Supply Philosophy	96-hour capability
• Resupply Period	90 days
• Crew Size	4
• Power	12.5 kW
• Number of Modules	4
• Orbital Altitude	200 to 230 nmi
• Orbital Inclination	28.5°
• Vehicle Attitude	Universal - no restrictions
II. EXPERIMENT (OPERATING)	
• Pressurized Equipment	
Pressure	1 atm
Humidity	60% max
Temperatures	-28 to 44°F (240 to 280°K)
(Typical Ranges)	32 to 103°F (273 to 313°K)
• Unpressurized	
Temperatures	-118 to 62°F (190 to 290°K)
(Typical Ranges)	44 to 69°F (280 to 294°K) 71 to 89°F (295 to 305°K)
• Number of EVA's	1 every 7 days (only)
• Airlock Repressurizations	1 every 20 days (2 men)
• Thermal Control	
Pressurized Active Cooling Load	0 to 8.5 kW*
Unpressurized Active Cooling Load	0 to 8.5 kW*
III. VEHICLE DESIGN CHARACTERISTICS	
• Atmosphere	
Composition	air
Pressure	1 atm
Humidity	43°F(6°C) DP to 70% RH
Temperature	65 to 80°F (18 to 27°C)
CO_2 Level	5.0 mm Hg
• Repressurization	1 time for largest compartment
• Crew Data	
Metabolic Level	560 Btu/man-hr (164 W/man)
CO_2 Generation	2.18 lb/man-day (0.99 kg/man-day)
O_2 Consumption	1.85 lb/man-day (0.84 kg/man-day)
Water Consumption	4 lb/man-day (1.82 kg/man-day)
Wash Water	10 lb/man-day (4.54 kg/man-day)

*Detail analyses of payload equipment cooling load is required to refine this cooling load division.

Table 5-9

SUBSYSTEMS SELECTED FROM AVAILABLE HARDWARE/TECHNOLOGY

Subsystem	Selection	Source
•Crew accommodations		
Waste management	Centrifugal separator	Orbiter
Crew equipment	Restraints, pers gear, et al	Orbiter/Skylab
•Environmental control/life support	1 atmosphere	
	Closed H_2O (vapor compression)	Spacelab experiment
	Open O_2 (LiOH for CO_2 removal)	Orbiter
•Electric power	25 kW solar arrays (12 kW at bus)	SEPS
	36 kWh batteries (12)	Orbiter
•Data management		
—Experiment	Distributed	Orbiter/Spacelab
—Vehicle	Centralized (1 Mbps serial data – 40K word memory)	Orbiter
•Communications	S-band	Orbiter
	Ku-band	Orbiter
•Stability/control	CMGs (3) (18,000 ft-lb-sec each)	Skylab – Improved
	Sensors (edge tracker, gimballed star tracker, solar)	Orbiter/Skylab
•Reaction control/ propulsion	Cold gas – N_2	Skylab
	60K-lb-sec total impulse	
	14 thrusters at 200 lb each	
•Structural/mechanical	Modular – primary structure	Spacelab
	Docking assembly	ASTP

The MOSC pressurized manned modules consist of one or two Spacelab 13.32 feet (4.06 m) outside diameter cylindrical segments each 8.79 feet (2.68 m) long. The cylindrical portion of the shell is stiffened with equally spaced integral longitudinal ribs and rings spaced every 7.28 inches (185 mm) along the length as shown in Figure 5-22. Integral end flanges provide a bolted and sealed interface with the cylindrical segments and with the conical end dome. All stiffening ribs are located on the inside providing for equipment attach points without penetration of the pressure shell membrane. The membrane is 0.062 inch (16 cm) and the internal stiffeners are 0.98 inch (2.50 cm) high, measured from the outside surface. The integrally stiffened conical structures are used to make the transition from the 159.8 in. (4.06-m) diameter to the 5.51-foot (1.68-m) docking interface. A conical section of similar design, which must be strengthened to withstand reverse pressure, is incorporated in the habitability module to provide an EVA airlock.

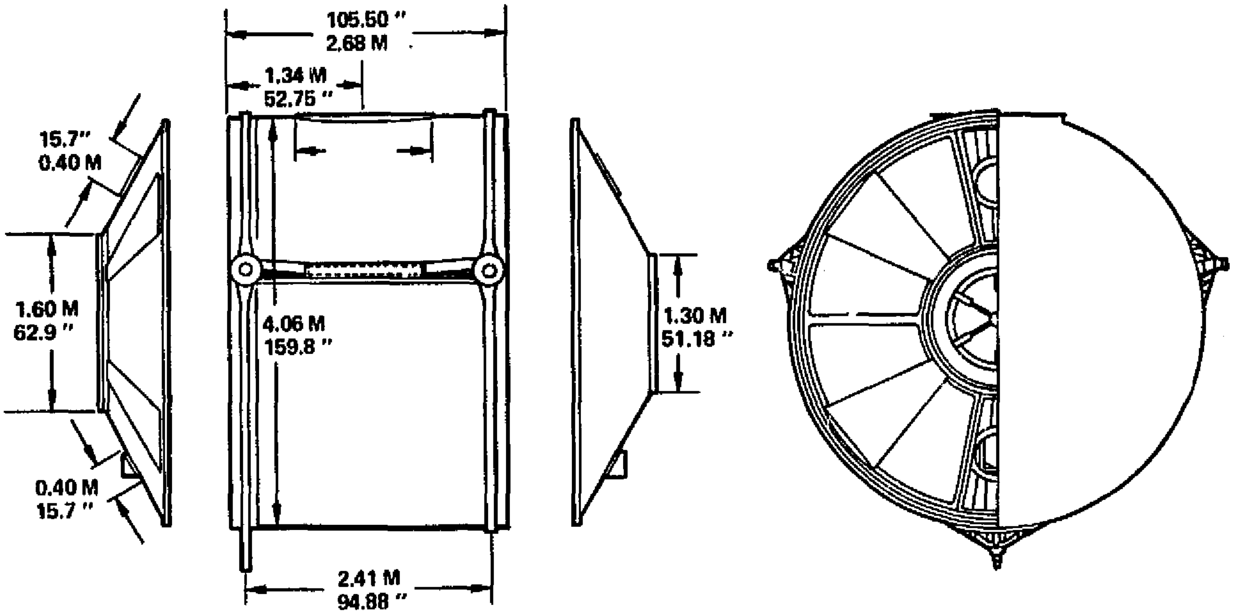

Figure 5-22. Spacelab Basic Module

Solar Array Orientation Turret

The solar array turret is supported at the forward end of the subsystem module by a short pressurized length of tunnel, which provides access between logistic and subsystem modules. The reduced diameter of the access tunnel provides an external annular clearance envelope for (1) the stowage of the retracted foldout arrays within the 15.0-foot diameter Orbiter cargo bay installation envelope, 2) operational clearance for the rotational path of the solar arrays during various MOSC vehicle orientations, and 3) stowage for high-pressure gas bottles. The tunnel membrane is stiffened by integral ribs in an isogrid pattern. The turret is a double cone configuration with a 110-inch (2.79-m) diameter center cylindrical section 36 inches (0.914 m) long. An additional short section of integrally stiffened tunnel is provided at the forward end to interface with the international docking assembly. The tunnel would also serve as an IVA airlock for servicing the dynamic-rotating seals of the solar array turret.

Hatches and Viewports

The basic MOSC vehicle has a total of seven internal hatches. Of these, four would be in the international docking assembly between the core vehicle and the logistic and payload modules. Three would be internal to the core vehicle and could be the international docking hatch door or a full 1-m door. The proposed door is aluminum honeycomb with 0.016-inch 2219-T87 aluminum facing. The hatch door incorporates a 6-inch (15.24-cm) diameter viewport located in the center of the hatch face. Mechanical force is used to obtain proper sealing by forcing the hatch to compress the soft sealing surface. To pressurize and equalize pressure between compartments, adjacent valves would be provided in the hatch structure bulkhead.

The external hatches are located in the EVA airlock of the habitability module and the international docking assemblies at both outer ends of the vehicle. The EVA hatch would be an adaptation of the 1-m internal hatch. The international docking assembly hatches are 31.5 inches (80 cm) clear diameter. Two types of hatch movement were considered for opening and storing the hatch door. Depending on the location and local clear area stowage envelope, a swing hinge or an open and translate mechanism would be used.

In addition to the 6-7 inch diameter viewports provided in each hatch, general viewing windows are provided in each habitability module. Each of the individual crew quarters incorporates one 11.8-inch (30-cm) diameter viewport. In addition, the Baseline 4-Man MOSC configuration incorporates two 11.8-inch (30-cm) diameter viewports in the wardroom. The habitability module is equipped with a flanged ring of 51.18 inches (1.30 m) internal diameter to provide accommodation for a mission-dependent optical window and viewport. The ring is located on the top centerline and convenient to the mission equipment.

5.2.1.2 Secondary Structure

Docking Structure

The initial evaluation of the international docking assembly, Figure 5-23, determined that it could meet some of the MOSC operational requirements

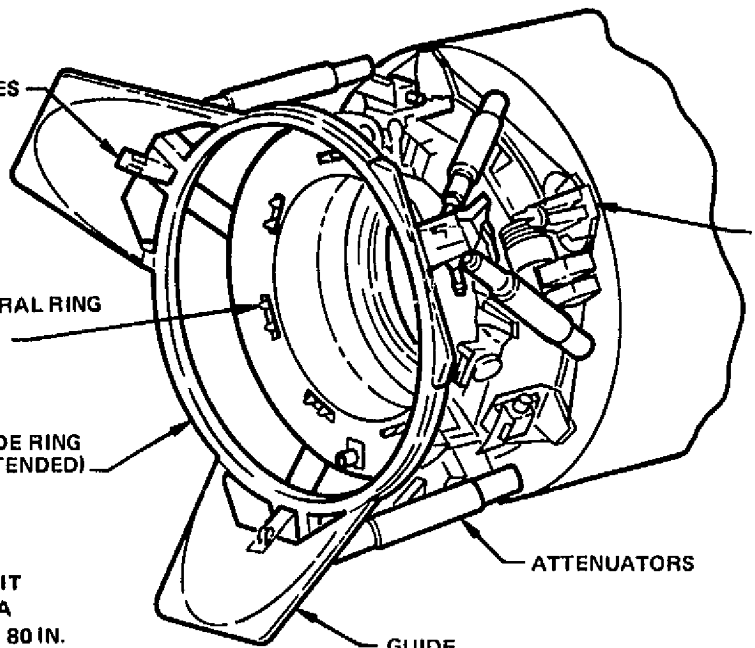

Figure 5-23. International Docking Mechanism

but would require modifications or MOSC program ground rule changes to be fully acceptable.

The docking assembly engagement velocities and alignments are satisfactory as the nominal Orbiter translation velocity is 0.5 ft/sec which is midrange in the docking assembly requirement. However, the order-of-magnitude difference in the momentum energy level and its effect on the attenuation system must be analyzed. The feature permitting emergency undocking with a separation impulse meets MOSC requirements. Also, the interface seal leakage of 10 to 15 grams per hour at 1 atmosphere is acceptable.

The ground rule for clear passage through the MOSC requires a 1-m diameter capability. The clear opening of the docking assembly hatch is approximately 30.5 inches (80 cm). This will require evaluation to assure satisfactory movement of crew, consumables, and equipment. A procedure for maintenance and/or repair and a method of transporting interfaces across the docking assembly will also be required.

5.2.2 Environmental Control/Life Support Subsystem

This subsystem is very sensitive to technology section for extended-duration missions, as the configuration span ranges from the fully open Skylab class to the fully closed advanced-technology class requiring minimum resupply. The MOSC Study analysis considered these two limits within the study guidelines of assuring a mission performance consistent with low cost.

Of particular importance to the MOSC Study were the physical requirements of weight, volume, power, and program costs. Cost effects were considered at two levels. First, cost was used in the evaluation of the candidate ECLS concepts, such as carbon dioxide control method. Secondly, ECLS subsystem cost was used as an element in the assessment of the MOSC as the initial space station for accomplishing space research and applications. The results and comparisons are presented in Book IV, Programmatics.

5.2.2.1 Requirements

The overall requirements are considered to be minimum for ECLS support of both space station operations and the payload activities based on crew and electrical power heat loads, and are within the available radiator area of the MOSC concepts. Additional capability was provided to ensure that a flexible MOSC would be an orbital facility with sufficient resources to support growth versions.

5.2.2.2 Candidate Concepts

The alternate concepts for performing the various ECLS functions can be categorized with regard to closure, i.e., the degree of recovery for reuse of oxygen and water. Open-loop concepts cost less initially and are simple; however, resupply costs may be high for large crews and long-duration missions. Conversely, closed-loop concepts are more complicated and cost more initially, but resupply needs are minimal. Lower-level subsystems options also exist within the various alternates available for a given degree of closure. The number of alternates considered for the MOSC was reduced by an initial screening that eliminated all but the most competitive subsystems and those currently receiving NASA development funding.

Figure 5-24 presents the ECLS subsystem alternatives that were considered and also shows the sequence and flow of trade data. The trade study options and recommendations are summarized in Table 5-10, and more detailed results are given in Figures 5-25 through 5-28.

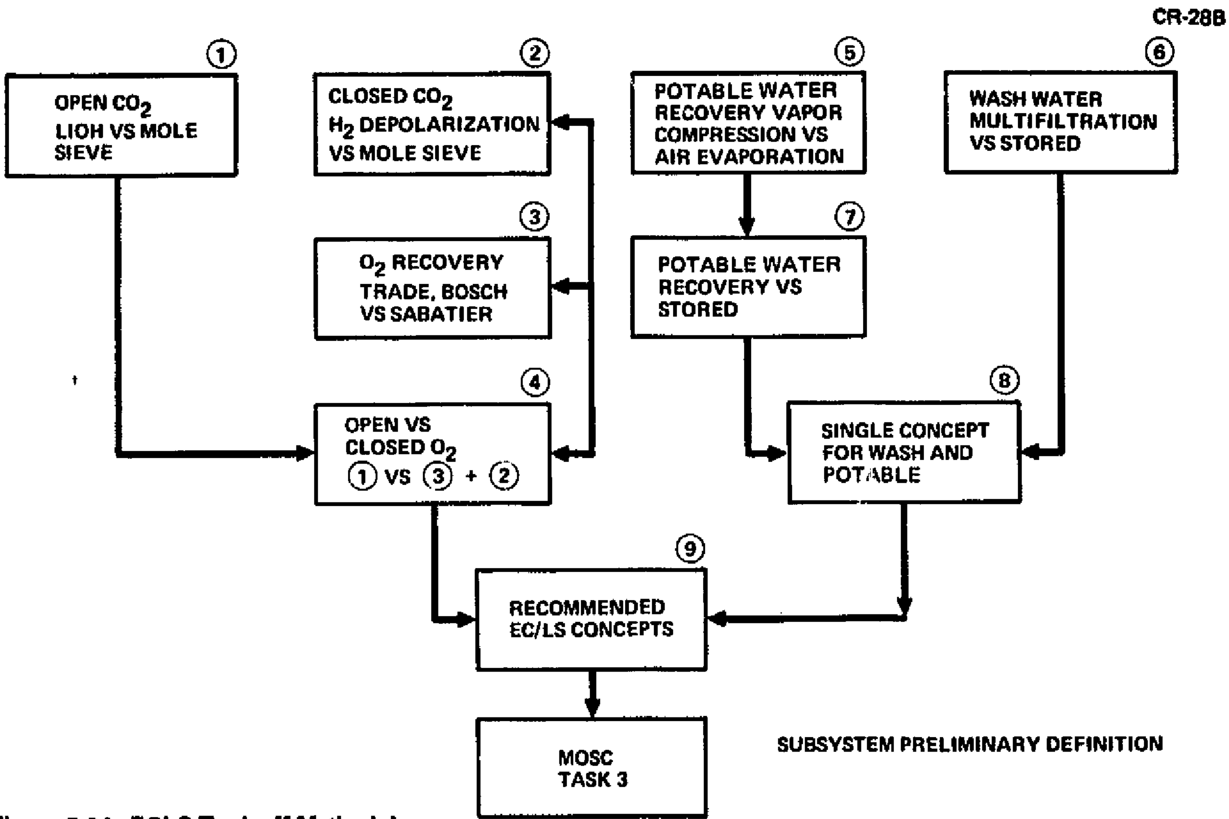

Figure 5-24. ECLS Tradeoff Methodology

The subsystem tradeoffs were based on total launch weight and cost. Final selections, however, were based primarily on cost. This selection criterion can be changed as the program evolves if launch weight becomes critical. Cost penalties used included launch fixed and expendable weights, and power and hardware nonrecurring and recurring costs. Launch costs were based on approximately \$12 million per launch and a 32,000-pound payload (maximum return weight) and a 65,000-pound payload (maximum launch capability).

Of the trades listed in Table 5-10, two are major in nature and are discussed in detail; these are open versus closed oxygen and single water recovery concept versus stored water. All other trade analyses support these two primary trades. Unless otherwise noted, the power costs were derived from

Table 5-10 (Page 1 of 2)

ECLS SUBSYSTEM TRADE STUDY SUMMARY

Trade	Alternates/Options	Rationale/Results	Recommendations
CO_2 removal method - open loop	• LiOH • Skylab mole sieve	Shuttle Orbiter system Skylab scaled to four-man system LiOH saves $5 million initial development Costs over entire MOSC mission are even	LiOH - Initial advantage and commonality with Orbiter
CO_2 removal method - closed loop	• H_2 depolarization • Molecular sieve	Initial costs are comparable Molecular sieve competitive only where cheap heat source available	H_2 depolarizer - Lower power costs and well-developed space station prototype
O_2 recovery method - closed loop	• Bosch • Sabatier	Initial costs are comparable Bosch power cost is offset by Sabatier's low efficiency	Sabatier - Comparable cost, simplicity, and low program risk
Open vs closed O_2	• LiOH + gaseous O_2 • H_2 depolarization, Sabatier with water makeup and and electrolysis	High initial costs for closed O_2 High power costs for closed O_2 offset by high resupply cost for open O_2	Open O_2 - Lower costs, simplicity, and lower program risk
Potable water recovery method	• Air evaporation • Vapor compression	Comparable initial costs and total costs Heat source needed for air evaporation	Vapor compression - Comparable costs, ease of operation, and better-developed space station prototype
Wash water recovery vs stored	• Multifiltration • Stored	Higher initial cost for recovery High resupply cost for stored water	Wash water recovery - Saves $2.5 to $13 million* over entire mission

*Depends on launch costs

Table 5-10 (Page 2 of 2)

ECLS SUBSYSTEM TRADE STUDY SUMMARY

Trade	Alternates/Options	Rationale/Results	Recommendations
Potable water recovery vs stored	• Vapor compression • Stored water	Higher initial costs with vapor compression (≈ $15 million) High resupply costs for stored water over entire program (up to $17 million*)	Potable water recovery - Lower total program costs
Single water recovery concept vs stored	• Vapor compression for wash and potable water • Stored water • Vapor compression for potable and multifiltration for wash water	Vapor compression costs (≈ $15 million more initially but saves $17 to $52 million* over entire mission)	Single concept - Costs less than separate concepts Large cost savings over entire mission Simpler and less program risk for single concept

*Depends on launch costs

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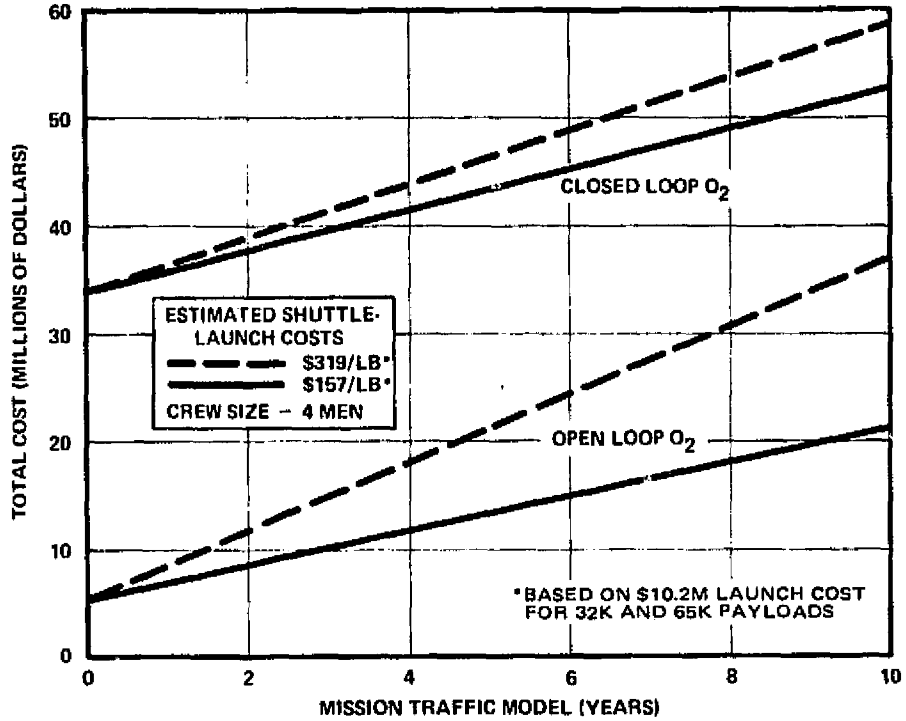

Figure 5-25. Oxygen Recovery Subsystem Trade Analysis Based on Total Cost

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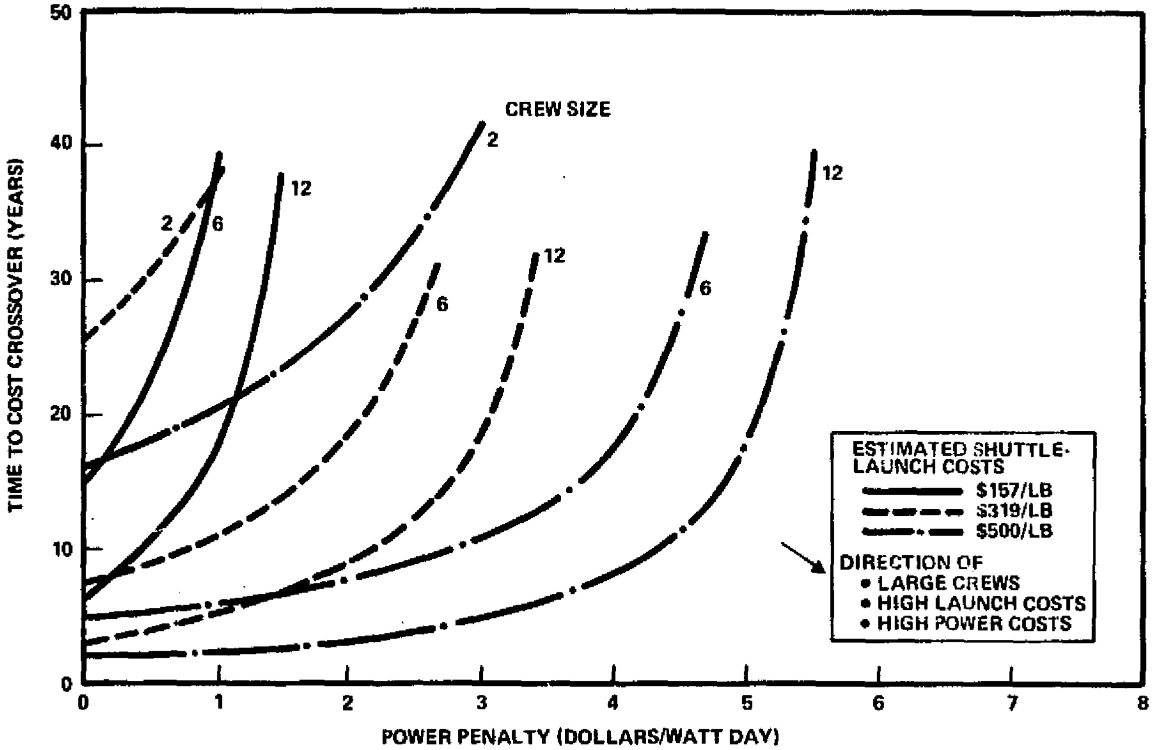

Figure 5-26. Total Cost Crossover Points for Oxygen Recovery Subsystem Trade Analysis

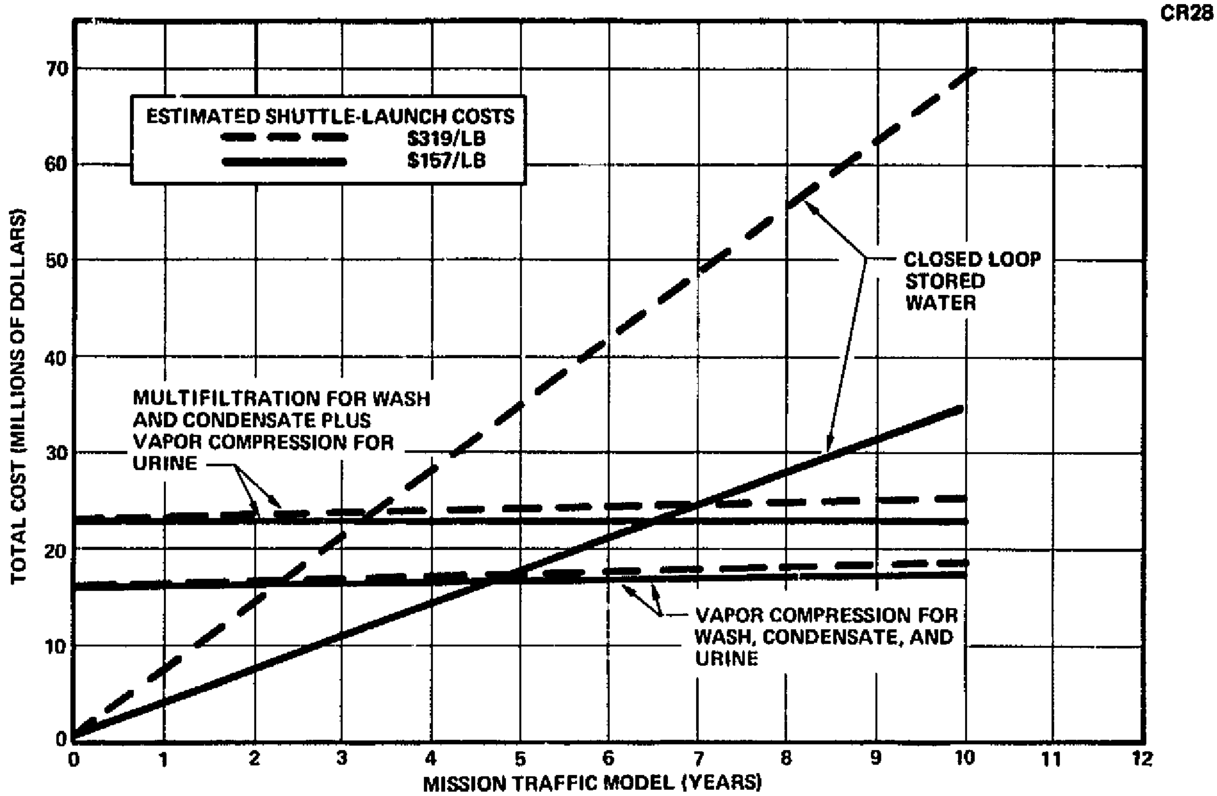

Figure 5-27. Water Recovery Subsystem Trade – Single Concept Analysis Based on Total Cost

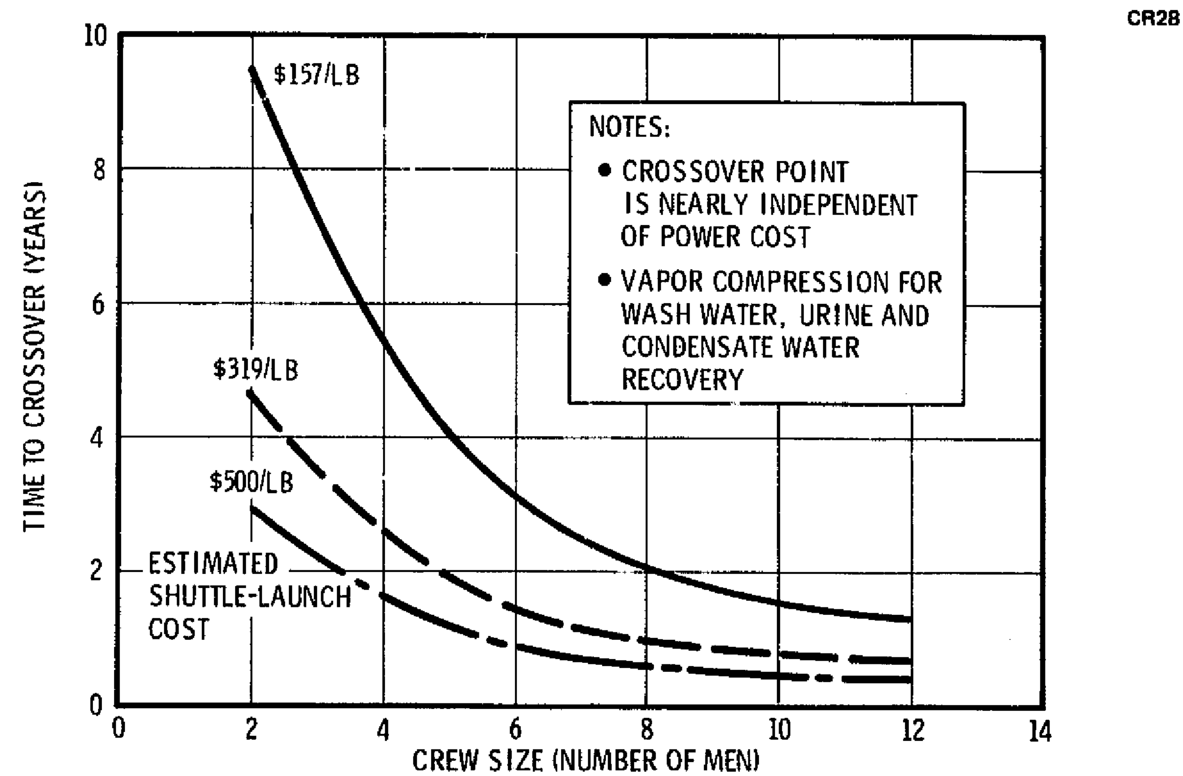

Figure 5-28. Crossover Time Points for Water Recovery Subsystem Trade Analysis

an earlier study in which a modular space station was STS-launched and solar-cell powered. Power costs derived in that study were \$2.13 and \$2.39/watt-day.

Figure 5-25 presents the oxygen recovery trade analysis which, for the crew size and cost penalties identified for MOSC, determined that O_2 recovery is not cost effective. Further data were developed for other crew sizes and cost penalties, as shown in Figure 5-26. These data show that O_2 recovery is cost effective only with large crew sizes (i.e., six or greater); low power input, and high launch costs. Even though the total launch weight is reduced by about 68,000 pound for a projected MOSC mission traffic model of 10 years, the open-loop oxygen system is selected for its lower total cost, simplicity, and commonality with the Orbiter subsystem.

Figures 5-27 and 5-28 present similar data for water recovery. Because of the relatively low power requirements for water recovery and high resupply weights for water resupply, water recovery is favorable from cost and weight standpoints. An initial investment of approximately \$15 million would result in a \$20 to \$50 million saving, depending on launch costs. Launch weight savings of over 200,000 pounds would be expected. Figure 5-28 indicates crossover point sensitivity to crew size and launch weight/cost penalty. Power cost is not included because the crossover point was found to be relatively insensitive to this parameter. These data also show that water recovery costs less for crews of two or greater and at launch costs more than \$157/lb for the effective mission traffic model of 10 years. Based on the positive trend of large cost savings and reduced total launch weight, water recovery was selected for the MOSC conceptual design.

5.2.2.3 Recommendations

Based on the cost and weight tradeoffs described in the preceding paragraphs, open oxygen and closed water loop concepts are recommended. The selected concept uses the Orbiter LiOH concept for CO_2 removal and gaseous oxygen resupply. A gaseous resupply was selected over a cryogenic O_2 resupply in consideration of reduced program risk, lower initial cost, and operational flexibility.

A single vapor compression unit is recommended to purify wash, condensate, and urine water for reuse by the crew. Selection of water recovery assumed the use of foods with low water content. Water recovery would be less attractive if food with more natural water content were selected at a later date. In this event, only wash water recovery, using multifiltration or reverse osmosis, would be considered.

The thermal control system selected for MOSC consists of space radiators around the exterior of the habitability module, and either single or dual circulating fluid loops. Use of a single loop using PP50 would be contingent upon results of current studies being conducted by NASA. A dual loop would use Freon in the radiator loop and water in the interior loop. Initial analyses show that about 11 kW can be rejected from a long habitability module MOSC. This performance may be marginal, and additional radiators may be necessary on the subsystem and logistics modules.

5.2.2.4 Baseline ECLS Subsystem Description

The ECLS subsystem was defined to meet the requirements presented in Table 5-8 derived from the trade analyses selections presented in the previous paragraphs.

Figure 5-29 is the schematic diagram of the baseline ECLS subsystem. Key elements are identified to show the general design and subsystem arrangement in the modules. The configuration and major components were selected on the basis of low cost, and as such represent state-of-the-art technology and minimum redundancy. With this approach, a design that meets the low-cost criterion while retaining a high probability of mission success was defined. Necessary precautions were taken in the design to ensure crew safety. This is accomplished by providing two separate pressurized modules with complete emergency provisions in each compartment in the form of integral emergency pallets. Sufficient redundancy at the component level and selection of simple concepts ensures a high probability of mission success. Exceptions to the redundancy philosophy have been taken in the thermal control system and the water recovery system, where redundancy at the component level is not expected to be adequate to obtain a sufficiently high reliability and so redundancy has been incorporated at the assembly level.

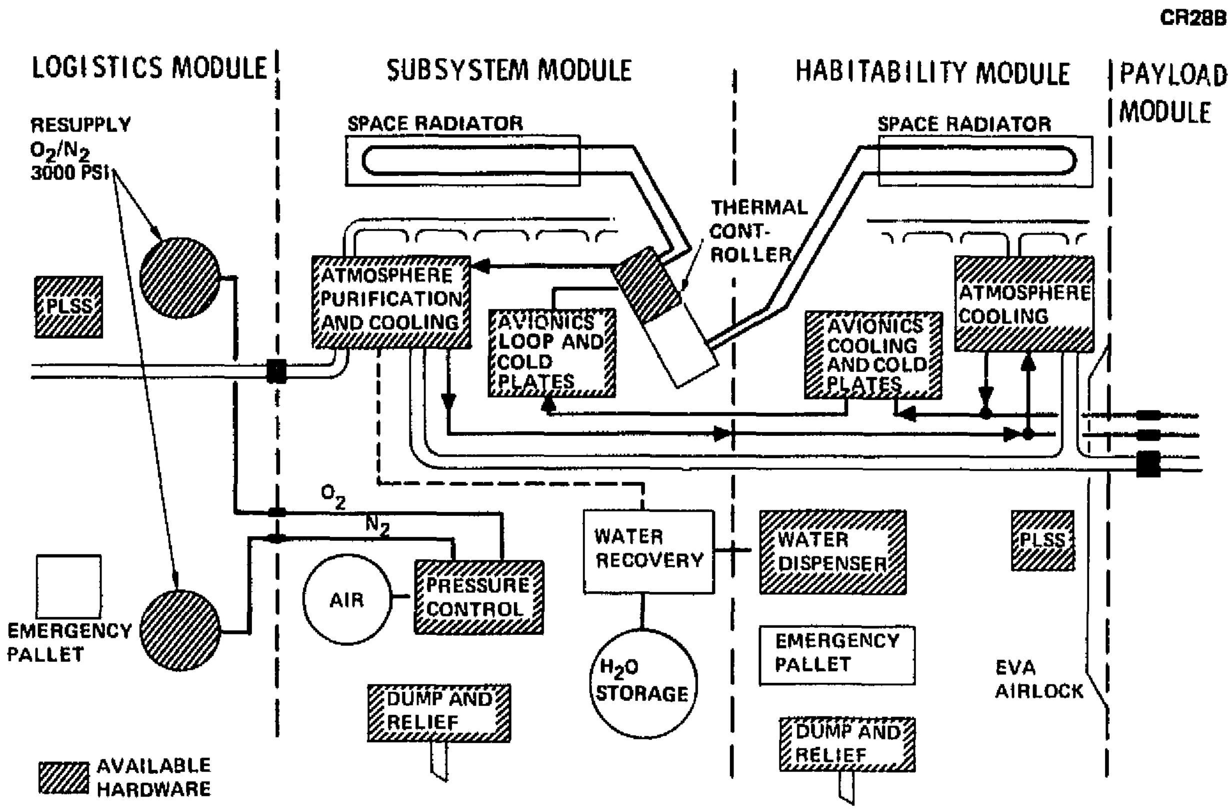

Figure 5-29. Baseline 4-Man MOSC ECLS Subsystem

Table 5-11 presents the detailed equipment list giving assembly characteristics and locations. The spares requirements, lines, liquids, and support structures were not included.

Referring to Figure 5-29, the ECLS equipment is primarily located in the subsystem module. Normal makeup oxygen and nitrogen are stored in the logistic module and supplied at reduced pressure (approximately 100 psia) to the pressure control assembly in the subsystem module, which admits gas to the cabin in controlled amounts to provide an atmosphere equivalent to the composition of air at 14.7 psia. Sufficient O_2/N_2 gas is stored in the subsystem module to repressurize the largest module. This supply also provides makeup O_2/N_2, if required, during unmanned periods before the logistic module is docked.

Atmosphere cooling is provided both in the subsystem and habitability modules. A condensing heat exchanger in the subsystem module serves to provide air cooling and control humidity. The habitability module heat

Table 5-11

BASELINE 4-MAN MOSC ECLS SUBSYSTEM EQUIPMENT LIST

Equipment	No. Req'd	Fixed Equipment Weight (lb)	Fixed Equipment Volume (cu ft)	Power (watts)	Expendables (90 day) Weight (lb)	Expendables (90 day) Volume (cu ft)	Location
O_2 and N_2 Storage	5	2025	77.5	0	1256	77.5	SM/LM
Repress. Air Storage	1	405	15.5	0	200*	15.5	SL/LM
Oxygen Pressure Regulation	1	20	0.4	2	0	0	LM
Nitrogen Pressure Regulation	2	40	0.8	4	0	0	1 in LM, 1 in SM
Atmosphere Pressure Control	1	28	0.6	24	0	0	SM
Cabin Dump and Relief	3	20	0.5	36	0	0	1 in each module
Airlock Pressure Control	1	7	0.1	0	0	0	HM airlock
PLSS Recharge	1	0.5	0.02	0	0	0	LM
Cabin Fans	2	72	4.4	606	0	0	1 in HM, 1 in SM
CO_2 Control	1	9	5.5	3	1069	53	SM/LM
Humidity and Temp Control	2	70	2.4	36	0	0	1 in HM, 1 in SM
Water Separation	1	11	3.3	44	0	0	SM
Distribution Ducts and Control Valves	Set	137	15	0	0	0	All modules
Avionics Fans	2	32	2.2	486	0	0	1 in HM, 1 in SM
Avionics Heat Exchanger	2	92	3.2	6	0	0	1 in HM, 1 in SM
Contamination Monitoring	1	33	1	50	0	0	SM
Fire and Smoke Detection	2	24	0.8	40	0	0	1 each in SM and HM, sensors in LM
Fire Suppression	2	40	1.4	0	0	0	1 in SM, 1 in HM
Water Recovery	2	360	9	57	31	1.8	Redundant units in SM
Catalytic Burner	1	80	4	90	20	0.9	SM
Water Dispenser	1	15	1	26	0	0	HM
Coolant Water Circulation	1	10	0.3	53	0	0	SM
Radiator Circulation	2	40	1	274	0	0	SM airtight compartment
Interloop Heat Exchanger	2	60	4	0	0	0	SM airtight compartment
Thermal Capacitors	10	275	2.5	0	0	0	SM airtight compartment
Regenerative Heat Exchanger	2	30	2	0	0	0	SM airtight compartment
Crew Prebreathing	4	40	2	0	0	0	Airlock area
Cold Plates	16	135	4.2	0	0	0	4 in SM, 2 in HM, 10 for thermal capacitors
Portable Life Support	4	412	28.4	0	0	0	HM airlock
Emergency Pallets	2	940	18	0	0	0	End modules

*Not normally used

exchanger only provides sensible cooling. Sufficient cool air is passed through distribution ducts to the logistics module to cool the small amount of equipment located there.

Separate avionics cooling loops are installed in the subsystem and habitability modules for the purpose of air cooling rack-mounted avionics. This concept

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reduces the possibility of cabin atmosphere contamination by outgassing avionics and also increases heat rejection efficiency over cabin air-cooling techniques. Separate avionics cooling is not necessary in the logistics module because there will not be any operating avionics located there.

A contamination monitoring unit is located in the subsystem module for the purpose of measuring key contaminants that might be anticipated in the MOSC. The unit is a combination mass spectrometer and gas chromatograph and serves the additional function of experiment support.

Fire and smoke detection is provided by dual units located in subsystem and habitability modules. Sensors for the units are provided in all MOSC modules and would be located adjacent to potential fire hazards. The fire suppression subsystem consists of fixed equipment in avionics bays, and hand-held units for augmentation and to cover areas where the probability of a fire is low.

Potable water for crew consumption and hygiene is provided by a water recovery subsystem which produces potable water from crew urine, wash water, and condensate. The system consists of redundant vapor compression assemblies, each of which is capable of processing all water needs for an 18-hour time period. Sufficient water storage is provided for 2 days of crew needs. This allows for transient crew output/usage and compensation for maintenance downtime. A water dispenser supplies hot and cold water for crew use.

Portable life support units are stored near the airlocks for crew use during EVA and emergency rescue operations. Prebreathing apparatus is located in the same area. Emergency pallets are located in each of the two outer-end modules. This includes the logistics module and pressurized payload modules; however, if an unpressurized payload pallet is docket to the habitability module, then the emergency pallet is located in the habitability module. The units support the crew in the event of a failure of the primary ECLS subsystem and/or a hazardous condition requiring crew rescue. Each emergency pallet contains essential life-support elements for four crewmen during the 4 to 7 days projected for a minimum turnaround STS rescue mission. These include potable water, food, cooling, atmosphere purification, and power supply.

The thermal control subsystem consists of dual fluid loops with heat rejection via an externally mounted radiator system. The radiator loop uses Freon 21 circulated through radiators located on the habitability and subsystem modules. The initial analysis determined that this provides a marginal radiator area. Detailed analysis may determine the need for additional radiator area on the logistic or experiment modules. Thermal capacitors are installed in the Freon loop to damp orbital fluctuations in radiator performance.

Heat is transferred to the Freon loop from the internal water loop via an interloop heat exchanger. The temperature of the Freon entering the interloop heat exchanger is controlled by a regenerative heat exchanger. A portion of the Freon passes around the radiator to obtain a constant 35°F temperature. This ensures that the water-loop temperature does not fall below the freezing point.

Redundant Freon loops are provided because of this element's criticality and the difficulty of maintenance. To prevent possible contamination of the MOSC atmosphere, all Freon equipment is located external to the habitable area or in a sealed compartment in the subsystem module.

The internal water loop collects heat from the various heat exchangers and cold plates within the modules and rejects it to the interloop heat exchanger. Redundancy is provided in the water loop at the component level, i.e., interloop heat exchanger and pumps. Other heat exchangers and lines are not redundant because they are static components and maintenance of them is practical.

Thermal control provisions are not provided for frozen food refrigeration in the baseline concept. If frozen food is later added to the crew's menu, provisions for a refrigeration subsystem must also be added. Inasmuch as the MOSC mission guidelines do not restrict the orbital attitude, use of the

Skylab radiator concept for refrigeration subsystem heat rejection may not be practical. Addition of a suitable flat radiator also may cause Orbiter bay envelope difficulties, which would dictate a deployable concept. Other approaches to a refrigeration subsystem may be necessary, such as the heat pump or thermoelectric concept.

5.2.2.5 Growth Subsystems

Important ECLS subsystem design considerations result when the growth or alternative versions of MOSC are contemplated. Larger crew sizes for example result in larger expendable resupply requirements, which place more emphasis on closed oxygen and water loops. The baseline design recovers water, but not oxygen. The larger the crew size above the four-man baseline level, the more attractive oxygen recovery will become. Due to the relatively low initial cost of the open-loop oxygen concept, an oxygen recovery subsystem can be added to a future design because the total cost tradeoff should shift toward the closed-loop subsystem.

Several advanced missions also may be considered for MOSC, such as synchronous, interplanetary, and lunar, which would require more costly resupply. All these concepts make closed ECLS subsystems virtually a requirement.

The tradeoffs performed to select the MOSC ECLS concept assumed unlimited availability of Orbiter launches to support MOSC. Restrictions could very well occur at a later date, depending upon traffic models, Shuttle turnaround time, and availability of Shuttle vehicles. Under these conditions, closed ECLS systems would be reconsidered because fewer Shuttles launches would be available for resupplying expendables.

The closed-loop oxygen subsystem would be required in all the examples of MOSC growth configurations mentioned.

5.2.3 Crew Accommodations Subsystem

5.2.3.1 General Habitability

Initial definition of crew operations and requirements was established on the basis that the MOSC will be a continuously manned operational space system. Thus, the study evaluation was a composite of Skylab experience gained in pioneering the extension of R/D manned space flight (SL-4 was 84 days) and advanced manned space studies, in which detail timelines and operations analyses were conducted in defining the sophisticated operational space facility, based on a high-traffic mission model.

Manned spaceflight experience, in particular the Skylab program, has shown that in general, a unidirectional (one-g) orientation of spacecraft interiors is the most habitable and perceptually adaptable approach. This approach has been followed in the Shuttle and Spacelab programs and will allow maximum utilization of existing structures and facilities in MOSC. A general adherence to a one-g orientation, however, should not prevent the utilization of the weightless environment to provide the most effective use of the interior volume such as vertical bunks, overhead stowage, and multiple orientation of crew quarters.

Various interior layouts and crew timeline studies have shown that the optimum arrangement for spacecraft in the 14-foot diameter range is with the floor parallel to the longitudinal axis. Utilization of this arrangement also maximizes the use of Spacelab structural and interior elements.

5.2.3.2 Crew Quarters

In the MOSC habitability module, quarters exist for each of the crew which contain a sleep restraint, adjustable lighting, adjustable ventilation, communications, a writing surface, crew restraints, and stowage provisions for personal equipment, off-duty equipment, tissues, bedding, garments, and trash. Isolation from sound and light is important and can be provided by design, materials, and location of the crew quarters.

Each of the crew quarters has a minimum free volume of 80 ft^3, with a floor-to-ceiling dimension of approximately 78 inches.

5.2.3.3 Personal Hygiene/Waste Management

The three-man Skylab crew found that a single combined waste management/hygiene compartment caused operational timeline inefficiency. Accordingly, the MOSC configurations for crews of four provide separte hygiene and waste management areas to allow a more efficient utilization of crew time. Each area should provide a minimum of 70 ft^3 of free volume. The equipment to be installed in the waste management compartment includes: fecal collector/processor, urine collector, tissue storage, and contingency urine/fecal collection bags. Personal hygiene items (i. e., hand/body) are stored outside the waste management compartment. Personal hygiene is accomplished in a free volume adjacent to the storage cabinets. The waste management compartment would be acoustically and physically isolated from the remainder of the module. The air flow would be into the compartment with filtered outlet air. For the three-man crew configuration a single combined hygiene/waste management compartment with a minimum volume of 100 ft^3 was provided.

In all cases, the urine and fecal collection subsystem is based on air flow entrainment. The use of direct bag collection would be considered as a contingency approach.

Partial- and whole-body cleaning will be accomplished by wash cloth wetting/rinsing, using air flow entrainment for water collection. An enclosed chamber "sink" has self-serving entrance ports for the hand and a window for viewing. Water is supplied from a water heater through a manual dispenser. Soap may be in bar form or liquid in a dispenser. Air flow, which is supplied by an integral blower, carries water, or soap and water, to a centrifugal phase separator. The separated air passes back into the compartment, and the water/soap mixture is piped to the water recovery system. Proven flight-tested elements of this approach are available from Skylab equipment and a flight version of this approach may be developed for the Orbiter.

Although a whole-body shower is not a basic requirement, it should be considered as a means to improve habitability and, consequently, proficiency.

Considerable improvement in convenience, effectiveness, and crew time over previous flight units must be made if positive benefits are to be provided. Equipment for personal grooming and dental hygiene will consist of standard Skylab items modified with Orbiter-developed improvements.

The fecal/urine collectors will be the same as the units being developed for the Orbiter, with any design improvements resulting from initial Orbiter flights.

Several studies have been made of providing a laundry capability to clean clothing, bedding, towels, washcloths, and wipes. The weight penalty for a "throwaway" approach to these expendables is significant. For a four-man 90-day MOSC mission, these items would total approximately 600 pounds and 35 ft^3. Previous conceptual studies have concluded that development of a laundry is feasible and advisable in view of these penalties. A detailed study including development hardware is required before this decision can be finalized. A major parameter in such a study, in addition to such obvious factors as weight, cost, and technical feasibility, is the quantity of consumables that would still be required as contingency items in case of laundry system failure.

5.2.3.4 Food Management

The food storage, preparation, and eating facilities should have sufficient volume to permit concurrent food preparation, eating, and cleanup by the entire crew. A pantry concept that allows access to individual food items has been included. A hot and cold water dispensing system and a resistance oven similar to those used by the Orbiter would be provided. The pantry is sized for seven days of food storage for the entire crew. It is stored onboard for the first launches of the MOSC four-man baseline and six-man-growth configurations so the initial crews can devote their full time to commissioning

the MOSC. Subsequently, the pantry permits the crew to transfer food on a weekly cycle, thus minimizing the frequency of trips to the logistics module and the crew time required for operational activities.

The food management/wardroom volume is 450 ft^3. The food preparation/serving system being developed for the Orbiter will meet the minimum MOSC requirements. However, the addition of frozen food should be considered together with its support equipment requirements, as food variety plays a major role in crew well being and morale. The longer duration of the MOSC missions accentuates the need for providing improved crew habitability features to maintain crew proficiency.

5.2.3.5 Trash Management

Assuring adequate provisions for the effective collection and stowage of trash is critical. The Skylab mission generated approximately 2.2 ft^3/man/day of trash. About 65 percent of this was biologically active trash, such as food waste and tissues, and the remainder was passive trash, such as packing material. Since MOSC does not have the advantage of the 2,200-ft^3 trash tank on Skylab, the amount of trash inherent in the basic consumables must be minimized. Trash also represents a discretionary payload weight and crew time line penalty. A new method of deactivating and storing the trash must be devised. A reasonable estimate of trash generation on MOSC might be 1.5 ft^3/man/day, or a total of 540 ft^3 for a 90-day period.

A trash compactor appears to be an effective solution to the problem of reducing trash volume to a reasonable amount. This would reduce an anticipated 540 ft^3 of trash to about 135 ft^3. The trash would be stowed in the habitability module and the logistics module as volume becomes available. All trash would be transferred to the logistics module for return to Earth. Development of trash collection and the compactor is required. Development of an optimum means of deactivating biological trash is also required.

5.2.3.6 Crew Conditioning

Apollo and Skylab experience proved the importance of maintaining the crew's physiological status. Crew conditioning facilities have been provided. Based on this background and the crew mission debriefing recommendations,

sufficient volume for a minimum volume of 70 ft^3, with one dimension at least 78 inches, is required. This volume, which can be shared for other activities, is readily available in the main passageway and in the four-man habitability module adjacent to the EVA airlock.

5.2.3.7 Crew Restraints and Mobility Aids

Based on Skylab experience, a basic foot restraint capability should be provided throughout the vehicle. With few exceptions, foot restraints will provide adequate restraint for all tasks while allowing large reach envelopes that can be effectively exploited in zero-g. Special restraints for unique tasks such as sleeping are required.

Although much locomotion will be accomplished by controlled soaring, a system of handholds should be provided for body control and temporary restraint. Specific handholds are not always required; existing items and structures can provide this capability in their basic design.

It appears that development of crew restraint and mobility aids beyond those being developed for the Orbiter and Spacelab is not required. Some experiments may require the development of unique approaches however.

5.2.3.8 Equipment/Cargo Handling

Flight experience has shown that large objects can be effectively moved about in zero-g by a crewman using special handling aids. In fact, it is multiple small items, e.g., carrying bags, that tend to be a problem and require special provisions.

5.2.3.9 Consumables

Food will be stowed in the logistics module, the habitability module pantry will be restocked every 7 days. In order to maintain a 4-day contingency supply independent of that in logistics module, a storage volume for an 11-day supply must be provided in the habitability module. Contingency items, such as backup fecal collection bags, only require storage volume for 8 days.

5.2.4 Electrical Power Subsystem

5.2.4.1 Power/Energy Requirements

The total requirements of the power and energy support subsystems include both the MOSC subsystems and the payload groups. Figure 5-30 summarizes the energy and power requirements for MOSC payload groupings operating from 7 to 90 days. As may be seen, power levels of approximately 5 kW satisfy all but three experiments, which require 8 and 10 kW. Using Spacelab subsystem estimates of 3.9 kW, and adding a communications subsystem allowance of approximately 300 W based upon Modular Space Station data results in total power requirements of 12.2 to 15 kW, with the upper end satisfying all experiments.

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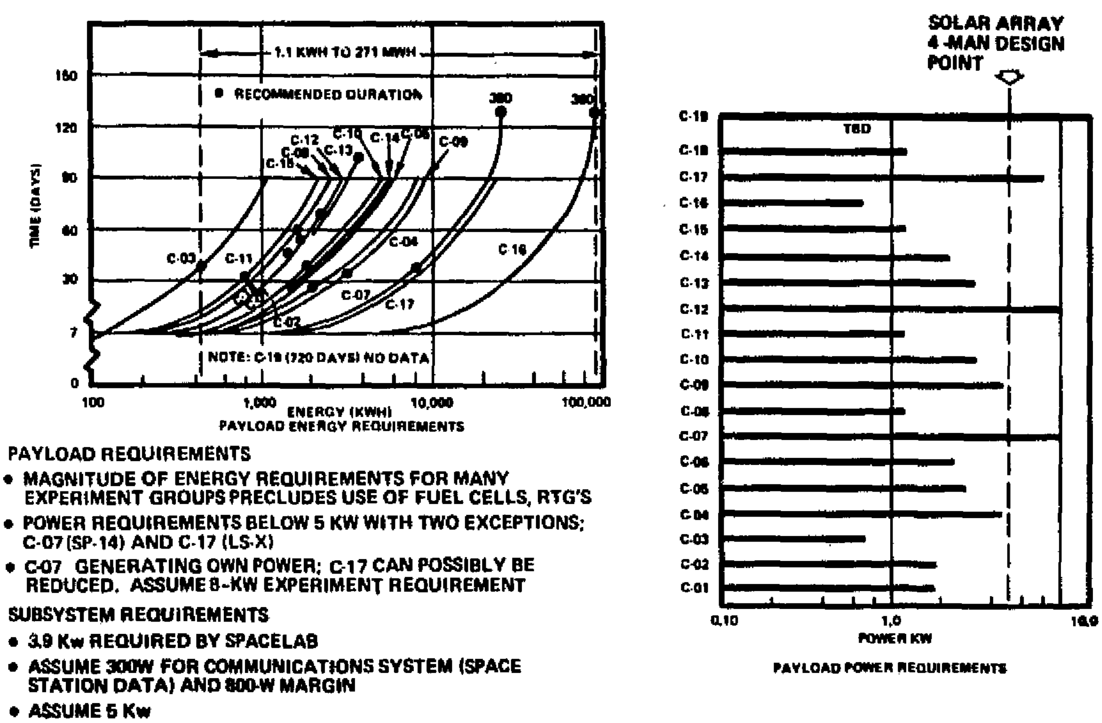

Figure 5-30. Baseline 4-Man MOSC Electrical Power Subsystem Requirements

5.2.4.2 Candidate Concepts

Initial candidate concepts for power subsystems included fuel cells, rigid and lightweight roll-out or fold-out solar arrays, radioisotope thermoelectric generators (RTG's), and Brayton cycle power conversion systems. As a result of the excessive reactant weight required for missions exceeding

7 days (as shown in Figure 5-31), the fuel cell concept was elinimated. RTG's were eliminated due to the low output (150 W) of existing units. Rigid arrays were eliminated due to excessive weight and the assumption that the development of foldout arrays stemming from the Solar Electric Propulsion Stage (SEPS) program will continue. The final candidates were, therefore, flexible solar array/battery systems and Brayton systems fueled by plutonium-238 (Pu-238) or curium-244 (Cm-244).

As shown by Figure 5-31, the use of the lightweight SEPS flexible solar arrays results in the lowest-weight system. The greater weight of the Brayton systems to due to the thickness of lithium shielding, as shown in Figure 5-32. Shield thicknesses were sized to maintain an acceptable crew radiation dose rate.

Figure 5-33 presents the bus power available compared with the solar cell and/or radiator panel area requirements of the various concepts. Although not directly tradeable, the Brayton cycle radiator area is of concern,

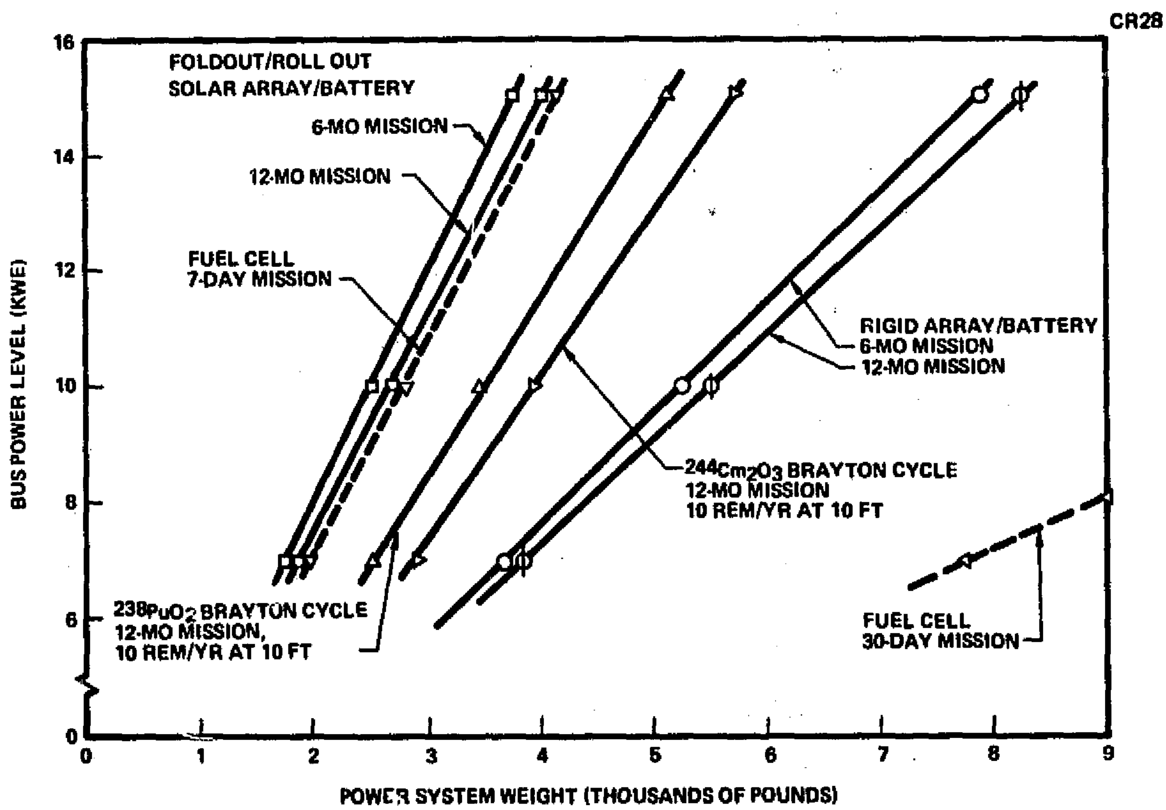

Figure 5-31. Power Subsystem Weight Versus Power Level for Candidate Concepts

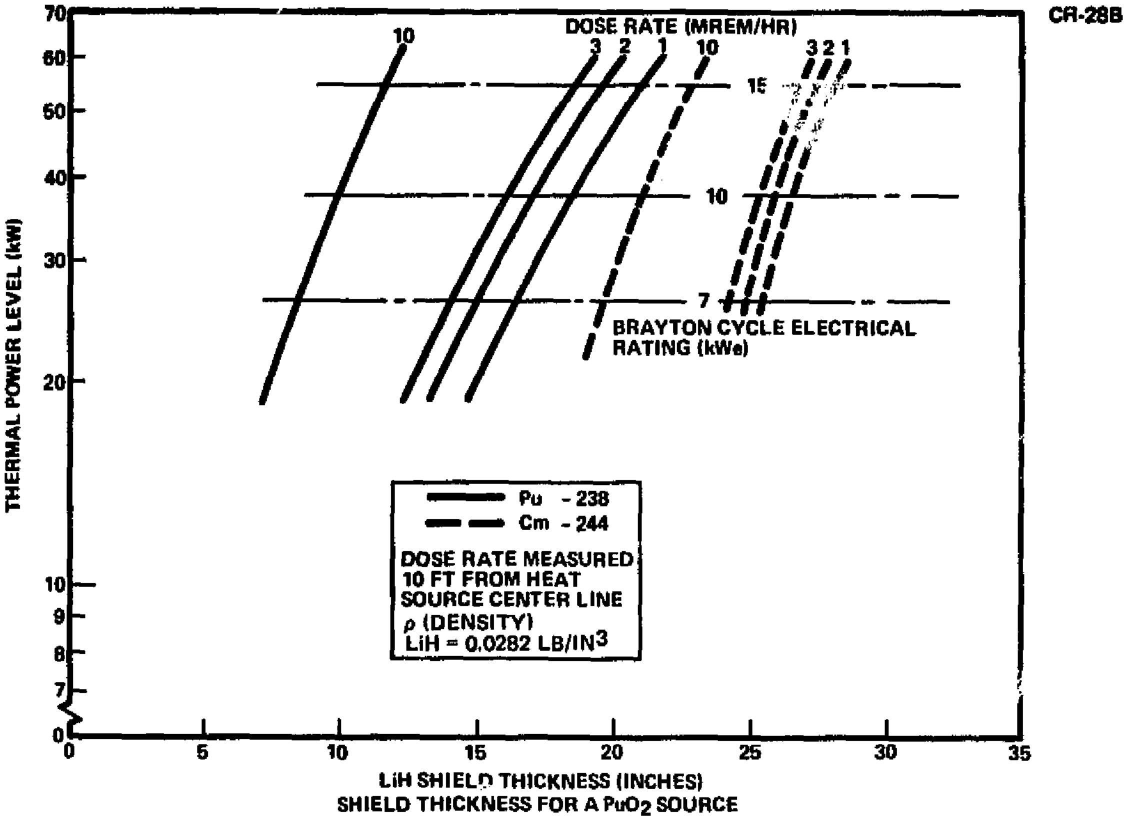

Figure 5-32. Brayton Cycle Radiation Shield Thickness Versus Power Level

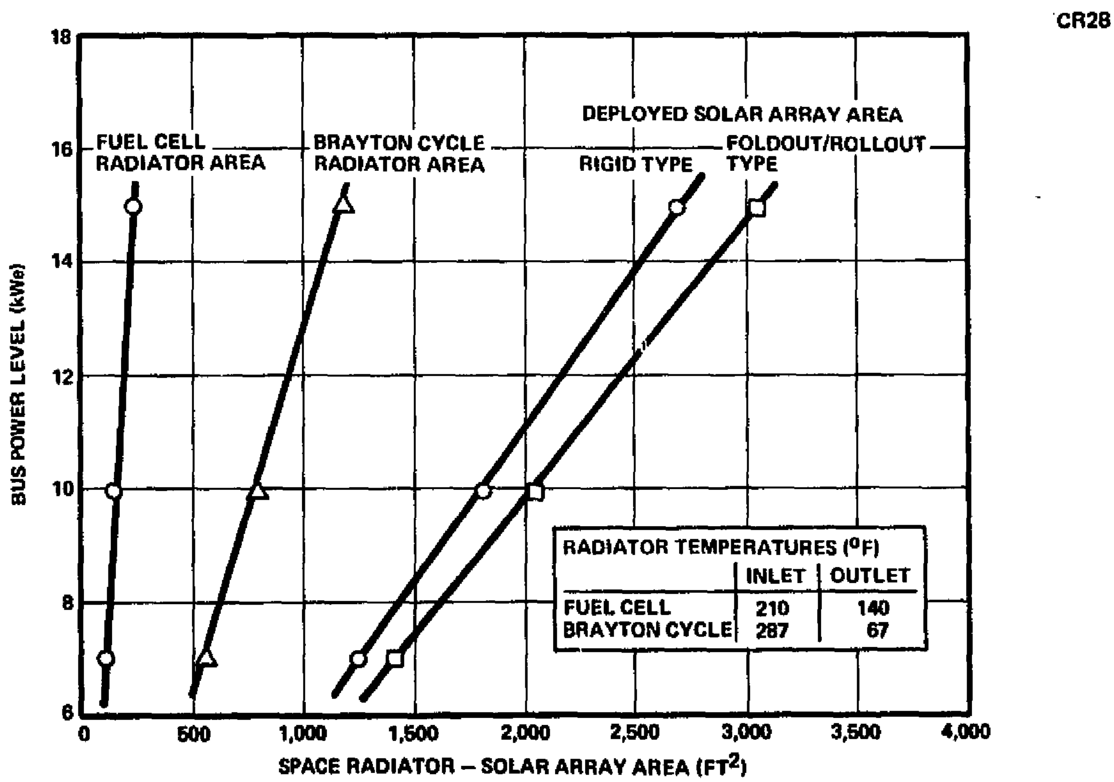

Figure 5-33. Power Subsystem Energy Transfer Area Vs Power Level

inasmuch as it competes with the ECLS subsystem for available external vehicle surface area. (Since the thermal control system, in rejecting 11 kW, already uses the surface area of the subsystem and habitability modules, the only remaining surfaces for the Brayton system's use would be those of the logistics and payload modules). In the case of solar arrays, area and location will require analysis due to shadowing and the torque required to move the solar arrays, which must be handled by the stabilization and control system.

5.2.4.3 Recommendations

The lightweight flexible SEPS array, provides approximately the required solar panel area for the MOSC configuration. Assuming the continuing development of the SEPS, coupled with the lack of available radiator surface area for the Brayton radiator helium-xenon working fluid, results in a recommendation of the SEPS solar array as the most attractive candidate for the power subsystem.

5.2.4.4 Baseline Electrical Power Subsystem Description

The electrical power subsystem (EPS) is composed of the major assemblies and subassemblies listed in Table 5-12. The EPS design provides a beginning-of-life (BOL) support capability of 13.2 kW for experiments and subsystems after deducting battery charging requirements, as shown by the load analysis of Table 5-13. This is further reduced to 12.8 kW with 8.6 kW allocated to experiments due to a distribution loss of 4%. The end-of-life (EOL) experiment allocation is 5.4 kW assuming a maximum degradation of 5% per year for a period of 5 years.

The solar array energy source consists of two independent wings with foldout panels deployed and retracted by "Astromast" masts. This concept is based upon the Lockheed Missile and Space Company (LMSC) design for the SEPS; MSFC Contract NAS8-30921. Each wing is further divided into two independently regulated and controlled power sources, each of which supplies regulated power to either or both of the two main 28-VDC buses, as shown in Figure 5-34. A potential exists for a reduction in panel area of approximately 40 percent with use of gallium arsenide solar cells which are

Table 5-12

BASELINE ELECTRICAL POWER SUBSYSTEM EQUIPMENT LIST

Components and Subassemblies	Quantity	Unit Weight (lb)	Unit Power(1) (W)	Unit Volume (ft^3)	Total Weight (lb)	Total Power (W)	Total Volume (ft^3)	Source	Location
Sola Array									
Array Panels	2	405	-	110	810	-	220	SEPS-LMSC	SM
Array Cannister (30" D x 60"M)	2	250	180 (Momentary)	24	500	0 (avg)	48	MSS/LMSC	SM
Mass Assembly	2	300		(Incl)	600	-	-	MSS/LMSC	SM
Orientation Assembly	1	463	100	1	463	100	1	MSS/LMSC	
Sun-Sensing Assembly	2	1	5	0.1		10	0.2	MSS	SM
Subtotals					2,375	110	269.2		
Power Source Regulation and Control									
Regulator (10 kW max, 7.5 kW avg)	4	60	-	1.0	240	-	4.0	MSS	SM
Power Control Unit (10 kW max)	4	14	-	0.1	60	-	0.4	-	SM
Subtotals					300	-	4.4		
Energy Storage									
Battery	6	205	-	1.5	1,230	-	9.0	MSS	SM
(28 Cell (7x4) 28V, 30% D of D 1 year)	6	205	-	1.5	1,230	-	9.0	MSS	HM
Battery Charger	6	5	-	0.1	30	-	0.6	MSS	SM
Battery Charger	6	5	-	0.1	30	-	0.6	MSS	HM
Subtotals					2,520	-	19.2		
Power Conditioning									
400 Hz Inverter (1.2 kVA)	3	40	180	0.5	120	540	1.5	DAC(DC-10)	SM
60 Hz Inverter (1.0 kVA)(2)	2	80	250	0.5	160	500	1.0	S/L	SM
28 VDC Regulator/ Converter	6	15	100	0.3	90	600	1.8	MSS	SM
(1.0 kW)	6	15	100	0.3	90	600	1.8	MSS	HM
Power Distribution									
Primary Distributor	1	30	-	1.0	30	-	1.0	S/L	SM
Secondary Distributor	1	30	-	1.0	30	-	1.0		SM
	1	30	-	1.0	30	-	1.0		HM
Subtotals					90	-	3.0		
Power Display & Control									
AC Control/Display Panel	1	6	-	0.3	6	-	0.3		SM
DC Control/Display Panel	1	12	-	0.5	12	-	0.5		SM
Primary Switching Panel	1	8	-	0.2	8	-	0.2		SM
Secondary Switching	1	10	-	0.4	10	-	0.4		SM
Panel	1	10	-	0.4	10	-	0.4		HM
Subtotals					46	-	1.8		
Interior Lighting									
Switching Panel	1	20	-	0.2	20	-	0.2	S/L	SM
	1	20	-	0.2	20	-	0.2	S/L	HM
Area Lighting(3)	8	5	24	0.2	40	192	1.0	S/L	SM
	4	3	30	0.1	12	120	0.3	S/L	SM
	6	5	24	0.2	30	144	1.0	S/L	HM
Portable Lighting	2	3	24	0.1	6	48	0.2	MSS	SM
	2	3	24	0.1	6	48	0.2	MSS	HM
Subtotals					134	552	3.1		
Exterior Lighting	4	5	24	0.2	20	96(4)	0.8	MSS	SM
Docking	4	5	24	0.2	20	96(4)	0.8	MSS	SM
	4	5	24	0.2	20	96(4)	0.8	MSS	HM
Orientation	8	2	5	0.1	16	40(4)	0.8	MSS	SM
	8	2	5	0.1	16	40(4)	0.8	MSS	HM
Acquisition	4	10	100	0.2	40	400	0.8		
Subtotals					246	1,224 (522 avg)	7.1		

(1) Array and battery power losses are included in the computation of 12 kW bus power vs. 25 kW array power.
(2) 50 Hz inverter may be substituted for ESTEC missions.
(3) SM: 6 Ceiling, 2 bench/console. HM: 4 airlock, 6 ceiling.
(4) Maximum values are shown for short-term lighting. The mission average approaches zero.

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Table 5-13

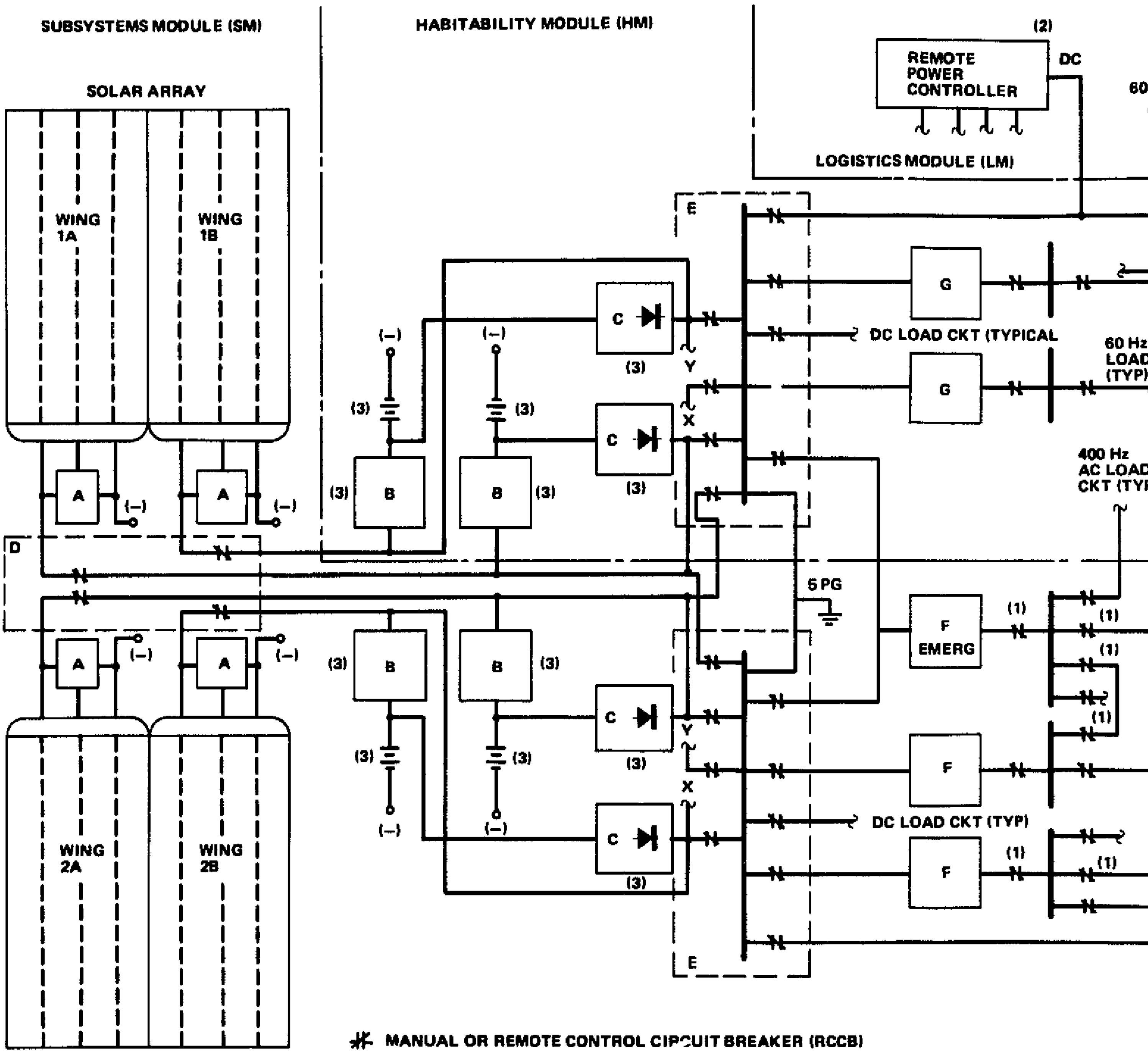
ELECTRICAL LOAD ANALYSIS

Support Requirement	28 VDC (kW)	115/200V 400 Hz 3Ø AC (kW)	115 V 60 Hz 1Ø AC (kW)	Total (kW)
Subsystems	2.6	1.3	0	3.9
Communications	0.3	0	0	0.3
Experiments	5.5	1.6	1.5	8.6
Total Load	8.4	2.9	1.5	12.8
Distribution (4%)	0.3	0.1	-	0.4
Total	8.7	3.0	1.5	13.2

Note: Power values shown are average load requirements.

concurrently in development by Varian. The array regulation assembly uses sequential partial shunt regulators for maximum efficiency and linear voltage control range.

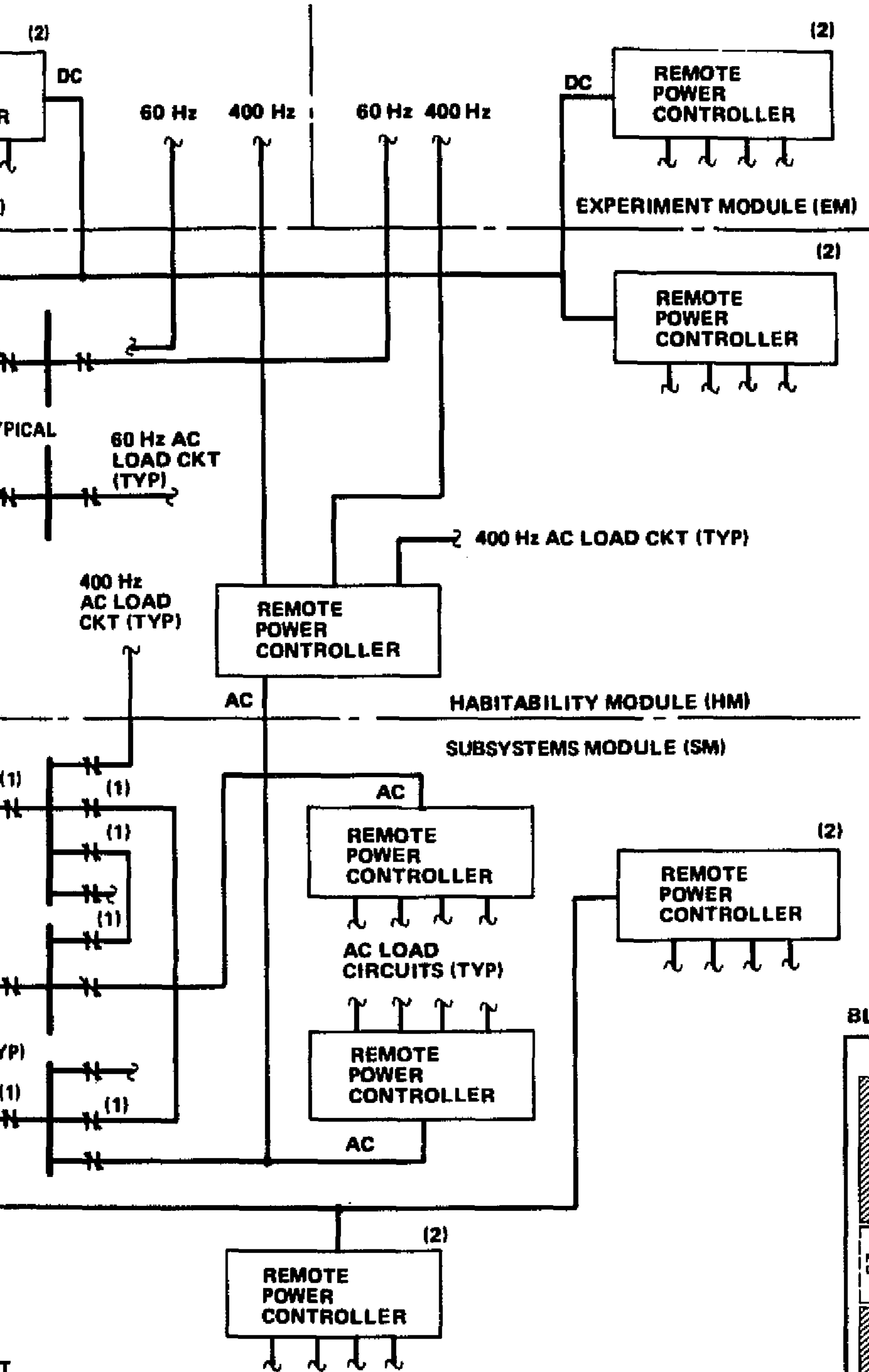
The deployment assembly deploys the lightweight foldout array by extending the Astromast assembly from the containment canister. Deployment may be either partial or complete; array retraction is also available if necessary to permit Orbiter/MOSC module docking and/or MOSC module recovery by the Shuttle Orbiter. The orientation assembly provides two-axis gimbal orientation under control of the sun-sensing assembly. Recycling is accomplished during eclipse after each orbit by a clutch-coupled brush-and-slipring assembly for each array wing. Rewinding of power cables is controlled by a stored-energy rewinding spring and inertial speed governor, which are released after the brush and slipring plates are decoupled. When rewinding is completed, the plates are recoupled by the clutch assembly.



MANUAL OR REMOTE CONTROL CIRCUIT BREAKER (RCCB)

A – SEQUENTIAL PARTIAL SHUNT REGULATOR AND POWER CONTROL UNIT
B – BATTERY CHARGER
C – DC CONVERTER/REGULATOR
D – PRIMARY DISTRIBUTOR AND PRIMARY SWITCHING PANEL
E – SECONDARY DISTRIBUTOR AND SECONDARY SWITCHING PANEL
(–) COMMON NEUTRAL CABLE FOR EACH WING; GROUNDED TO STRUCTURE AT SINGLE POINT GND (SPG)
F – INVERTER, 400 Hz 3 ϕ SINE WAVE, 1.2 KVA
G – INVERTER, 60 Hz, 1 ϕ SINE WAVE, 1.0 KVA (MAY SUBSTITUTE 50 Hz FOR ESTEC)

FOLDOUT FRAME



NOTE (1) INTERLOCKED CB'S; INVERTER AC OUTPUT CIRCUITS ARE NOT TO BE PARALLELED

NOTE (2) REMOTE POWER CONTROLLER IS ON OR A GROUP OF MUX–CONTROLLED SWITCHES

ESTEC)

BLOCK DIAGRAM SHOWING AVAILABLE HARDWARE

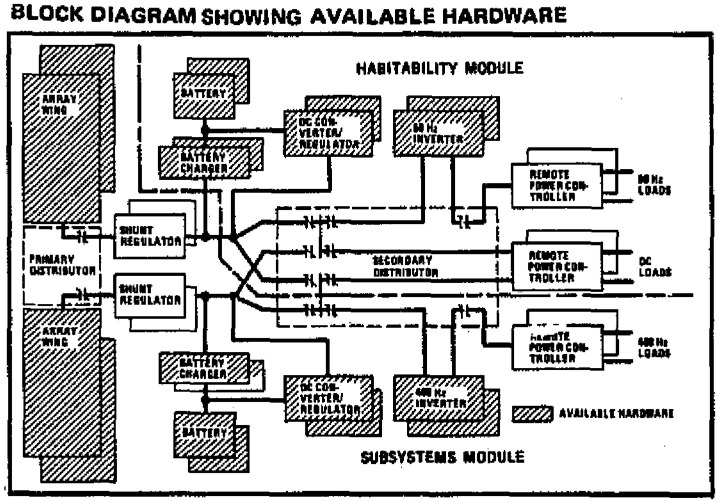


Figure 5-34. Electrical Power Subsystem Baseline 4-Man MOSC

FOLDOUT FRAME 2

The primary switching panel in the primary distributor allows power flow from the four solar array wing segments to be directed to any group of three energy storage subassemblies. Four such energy storage groups (a total of 12 batteries) are provided, with two in each station module. Thus, two totally independent power subsystems and two separable sources per subsystem are provided for high reliability, and these are normally operated in parallel at the main DC buses. Switching is performed by remote control circuit breakers (RCCB's) under multiplex control by the DMS.

The energy storage assembly consists of twelve 28-cell, 28-volt, 50-ampere-hour, hermetically-sealed, temperature-controlled (10 to 20°C), nickel-cadmium batteries, each with its own battery charger and battery discharge converter/regulator. These batteries, with modules replaceable on orbit, provide all the MOSC power during orbital eclipses, emergency power, and initial deployment and exchange of the subsystem module. The nominal average depth of discharge is 30 percent (70 percent maximum during normal operation), yielding a median battery lifetime and resupply period of one year. The discharge converter/regulator provides DC voltage boost and regulation during eclipse periods, while the sequential partial shunt regulators and the solar array provide regulation during periods of sunlight.

Secondary distribution and switching panels are provided in the subsystem and habitability modules. These receive and combine the solar power and battery as desired (normally in a fully parallel mode), provide a switching capability for electrical power subsystem reconfiguration, and supply power to the 400- and 50-Hz inverters. Switching is performed either manually or remotely by RCCB's for load branch circuits, depending on the criticality and type of load, accessibility of the switch, and cable size with regard to minimizing weight.

The inverters provide redundant 115/200 V, 3Ø 400-Hz AC power to all station modules, and 115 V 1Ø 60-Hz AC power to the habitability module, experiment module, and logistics module. A third 400-Hz inverter is provided for emergency power and backup to the two normal inverters.

Remote power controller subassemblies are provided for AC and DC load circuit control and protection. These are located according to assessments of weight savings and remote multiplex control requirements for such circuits. Each controller consists of a group of one or more multiplex-controlled switches, supplied by a common main bus RCCB.

Key electrical power subsystem specifications are listed in Table 5-14.

Table 5-14
ELECTRICAL POWER SUBSYSTEM SPECIFICATIONS

Function	
Solar Array Type	Flexible, foldout, based on LMSC design for SEPS.
Array Orientation Drive	Synchronous, continuous-drive, MDAC design.
Power Transfer Method	Spiral coil, trailing cable, unwound during eclipse with a power clutch assembly.
Battery Type/Capacity	Nickel-cadmium, 50 ampere-hours.
Battery Charge Control	Electrical switching, cell voltage cutoff, third-electrode backup, independent charge and discharge of 12 batteries.
Voltage Regulation	Array: Sequential partial shunt, closed-loop control. Battery: Pulse width modulation (PWM) series (buck/boost), closed-loop control, DC/DC converter/regulator.
Power Transmission	A 100 percent redundant, direct-current, with differential protection.
Power Conditioning	Bulk regulation for DC; modulator, redundant, nonparalleled inverters for AC; current-limited protection.
Power Switching and Control	Solid state for low power, electromagnetic for high power, remote power control by multiplexing. Automatic DMS supervisory control with manual display. Local manual control for isolation and backup. Remote control by telemetry for unmanned operation.

Assembly	Factor	Design
Solar Array	Blanket Area	2,668 ft^2 (248 m^2)
	Wings	2
	Segments/Wing	2
	Panels/Segment	TBD
	Wing Area and Dimensions	1,334 ft^2 (124 m^2); 31m x 4m (1,180 in. x 157 in)
	Panel Area and Dimensions	325 ft^2 (30.4 m^2; (76.2 cm x 398.8 cm)(30 in. x 157 in.)
	Solar Cells	250,920 cells; 2 cm by 4 cm, N/P silicon, 11.4 percent efficiency bare at atmosphere zero, 28°C; 8-mil cells with 6-mil covers; 2-ohm-cm base resistance
	Regulated Array Voltage	28 ± 1 percent VDC
	Initial Array Power	25 kW at mast (beginning of life)
	Sunlight/Eclipse Periods (300 nmi)	56 min/36 min
	Degradation Rates	10 percent (min) in 5 years; 25 percent (max) in 5 years
Orientation	Gimbal Axes	2
	Gimbal Range	α ±180 deg; β ± 235 deg
	Gimbal Angular Rate	4 deg/min tracking; 22 deg/min for unwinding cable or 180 deg/min for rotary clutch relay
	Orientation Accuracy	±8 deg
Energy Storage	Cell Capacity	50 amp-hr
	Replaceable Module	Four cells; 25 lb/module
	Battery Size	28 cells; 7 modules
	Battery Dimensions	L13 in. (33 cm), W 18 in. (46 cm), H15 in. (38 cm)
	Battery Weight	205 lb
	Total Batteries	12
	Initial Launch Weight	2,460 lb (12 batteries)
EPS Weight	Total EPS Weight Onboard	6,271 lb (including 380 lb of lighting)
	Depth of Discharge	Normal: 30 percent average, 70 percent maximum Contingency: 80 percent
	Design Life	Normal: 1 year Contingency: 300 cycles
	Emergency Capacity (12 batteries)	At full charge: 36 kWhr At minimum (30 percent) charge: 10.8 kWhr
	Temperature Control	10° to 20° C range, 13°C design point
Transmission	Voltage	28 ± 2 percent, 115 ± 3 VDC
	Circuits/Cable Size	4/double AL #1/0
	Nominal Current per Cable	250 A
Distribution	Load Bus Average Power	ISS: Initial - 13.2 kW 5-year - 12.0 kW with 10 percent min degradation 9.3 kW with 30 percent max. degradation
	Load Terminal Voltage	28 + 2-1/2 percent, -7 percent VDC; 115/200 + 2-1/2 percent, -7 percent vac; 400 ± 1 percent Hz, 3-phase, sine wave; 115 ± 10 percent vac, 60 ± 1 percent Hz

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5.2.5 Communications Subsystem

5.2.5.1 Requirements

The requirements for experiment analog and digital data transfer are listed by experiment groups in Table 5-15 and Figure 5-35. The major requirement shown in the table is one TV channel for 12 hours of continuous transmission and two TV channels for 1.6 hours of continuous transmission. The major requirement from Figure 5-35 is a continuous 10 Mbps over a 12.5-hour period. This rate is subject to review and possible reduction, and a lesser rate would actually be accommodated.

5.2.5.2 Candidate Concepts - Communications

The requirement for continuous data transfer over an extended period of time can only be accommodated by the Tracking and Data Relay Satellite Systems (TDRSS).

The proposed reduction of the Space Tracking and Data Network (STDN) to six stations (two others being retained for launch support) further substantiates the TDRSS requirement. Figure 5-36 illustrates the various communications links that must be furnished, and the composition of these links.

As indicated, the primary link between the ground and the MOSC is the TDRSS; the STDN links are retained for backup. In addition, communications links are provided with the Orbiter for station activation and resupply, for crew EVA operations, and for satellite spacecraft controlled by the MOSC.

The requirement for two video (4.5-MHz) channels, assuming C-02 requirements may be halved by time sequencing, will require the use of one of the two Ku-band single-access (KSA) channels with a bandwidth of 225 MHz. The Orbiter Ku-band transponder, operating in the FM mode, is presently being designed for one video channel, and an 8.5-MHz carrier above baseband, which is suitable for modulation by the two-voice and 128-kbps subsystem telemetry channel. Inasmuch as the expected bandwidth should not exceed 30 MHz, a second transponder carrying another video channel and up to 2 Mbps of experiment data is feasible. Obviously, care will have to be

Table 5-15

EXPERIMENT REQUIREMENTS FOR ANALOG/VIDEO TRANSFER

MOSC Payload Group No.	Analog		Color TV		B&W TV	
	Channels, Freq	Hours	Channels	Hours	Channels	Hours/ Channel
C-01	-	-	-	-	1 2	12 1.6
C-02	-	-	-	-	4	9.6, 1.5 0.24, 1.5
C-03	-	-	-	-	-	-
C-04	1, 4MHz	6.5	-	-	-	-
C-05	1, 4MHz	6.5	-	-	-	-
C-06	1, 4MHz	6.5	TBD	TBD	TBD	TBD
C-07	-	-	-	-	-	-
C-08	-	-	1	2.0	-	-
C-09	-	-	-	-	-	-
C-10	-	-	-	-	-	-
C-11	-	-	-	-	2	1.5, 1.5
C-12	-	-	2	0.5	1	1.0
C-13	-	-	2	0.5	1	1.0
C-14	-	-	-	-	1	9.3
C-15	-	-	-	-	-	-
C-16	-	-	TBD	TBD	TBD	TBD
C-17	TBD	1.5	-	-	-	-
C-18	-	-	-	-	-	-
C-19	TBD	TBD	TBD	TBD	TBD	TBD

taken to separate the carriers, ensuring that intermodulation products of the form $2W_2$-W_1 and $2W_1$-W_2 fall outside channel bandwidths; TDRSS amplifiers operating in a saturated mode require that careful attention be paid to intermodulation products.

Although the need to accommodate 10 Mbps of digital data on the return link is considered questionable, the allocation of a S-band single-access (SSA) channel providing two sub-channels in quadriphase at 6 Mbps total (maximum)

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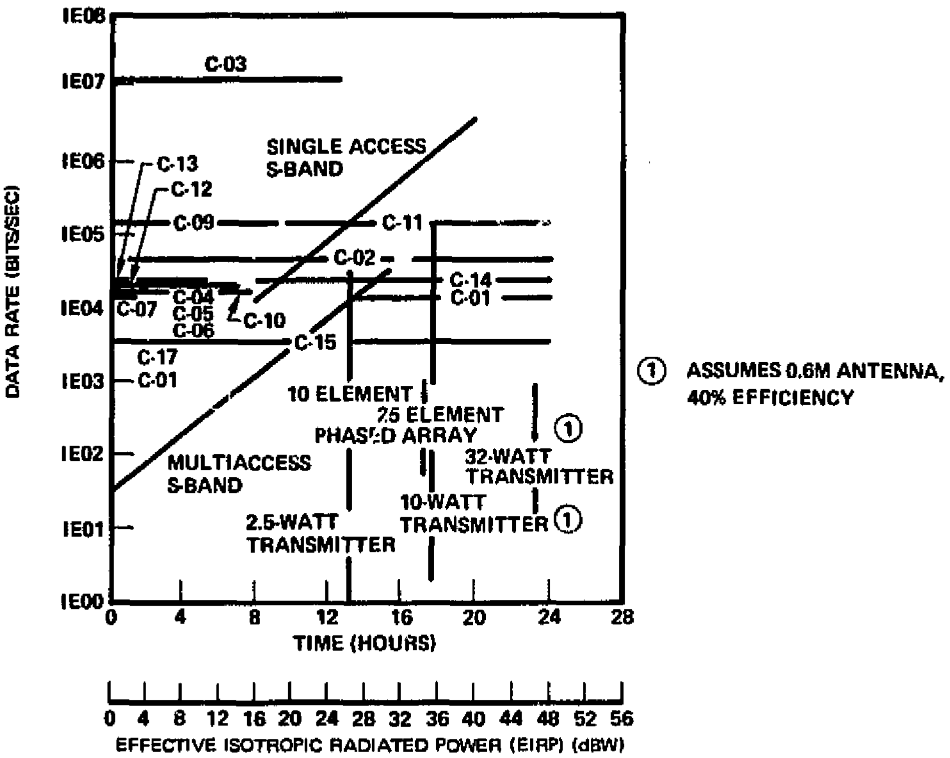

Figure 5-35. Experiment Requirements for Digital Data Real-Time Transfer

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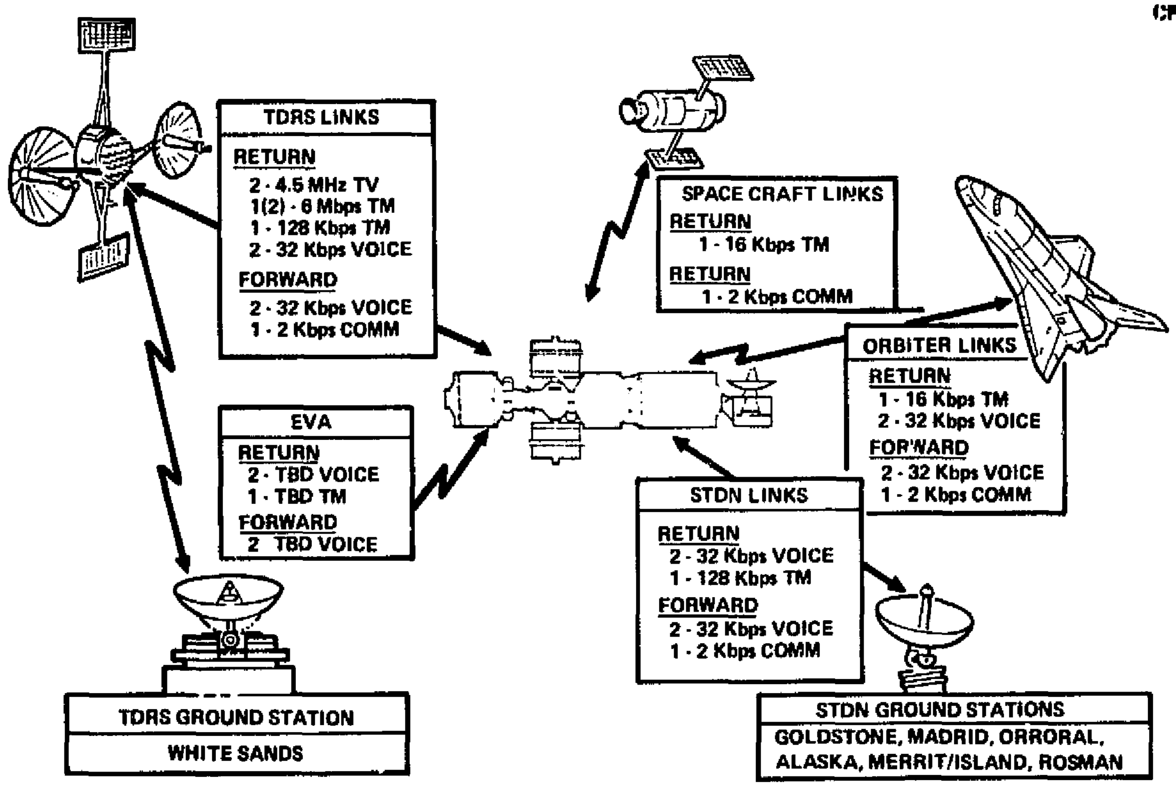

Figure 5-36. Baseline 4-Man MOSC Communication Channels

also is advisable. Should the need occur in the future, the Ku-band transponder could also transmit data at 50 Mbps (150 Mbps Vitterbi coded). However, only this one transmission would be possible in the available bandwidth, and its use is expected to be infrequent.

Similarly, all the various link requirements can be met with Orbiter hardware. Since these will have been developed, and production units manufactured, the only communications equipment subject to trade analysis appears to be S-band phased arrays baselined for Tug versus Orbiter S-band transmitters and antennas. Figure 5-35, which presents the experiment digital data requirements, also contrasts transmitter power versus 1-watt/element phased arrays as a function of data rates. Examining these data, either a 10-W transmitter and the Orbiter 0.6-m antenna or a 25-element phased array would meet the SSA requirements. However, unless the phased arrays are developed under the Tug program, they would require a detailed cost trade analysis.

5.2.5.3 Communications Subsystem Description

The communications subsystem, whose major assemblies and components are listed in Table 5-16, is almost entirely composed of Orbiter or modified Orbiter equipment. It provides a capability for ranging and data transfer between the Tracking and Data Relay Satellites (TDRS) and the White Sands ground station, the Spaceflight Tracking and Data Network (STDN), and also contains a low-power S-band system for MOSC/Orbiter or other free-flying vehicle communications. During the time frame that the MOSC will be operating, it is projected that communications subsystems will almost exclusively use the TDRS system, with the STDN retained for backup or emergency use only.

As shown in Figure 5-37, the S-band transponder assemblies operate in either the TDRS or STDN modes; the former mode requires that signal amplification be provided by the power amplifiers for transmission via the quadrant antennas and the preamp on receive. In the latter mode, full duplex voice and data transmit/receive is offered in addition to Doppler frequency turnaround, with the transponder operating in a coherent mode; tone ranging

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Table 5-16

COMMUNICATIONS SUBSYSTEM EQUIPMENT LIST

Equipment List	Location	Quantity	Unit Weight (lb)	Power (W)	Dimensions (in.)	Total Weight (lb)	Total Power (W)	Total Volume (in.^{3})	Source
S-Band Antenna Group									
PM Antenna	SM	4	2	N/A	4 x 4 x 3	8	N/A	192	Orbiter
FM Antenna	SM	2	2	N/A	4 x 4 x 3	4	N/A	96	Orbiter
Payload Antenna	SM	1	2	N/A	4 x 4 x 3	2	N/A	48	Orbiter
Switch Assembly	SM	1	8	*	8 x 5 x 7	8	N/A	280	Orbiter
Ku-Band Antenna Group									
Antenna	HM	3	25	N/A	Diameter = 2	75	N/A	N/A	Orbiter
Deployment Assembly (Includes Mast)	HM	3	150	N/A	Length = 180	450	N/A	N/A	Orbiter (Modification)
S-Band RF and Signal Processing									
Preamp Assembly	SM	1	20	25	19 x 6 x 7	20	25	800	Orbiter
PM Transponder	SM	2	23	15	19 x 6 x 7	46	15	1,600	Orbiter
Power Amplifier	SM	1	30	25	19 x 5 x 7	30	25	660	Orbiter
FM Transmitter	HM	2	30	24	19 x 3 x 7	60	24	800	Orbiter
Payload Interrogator	SM	1	20	10	19 x 5 x 7	20	10	615	Orbiter
PM Signal Processor	SM	2	18	12	19 x 4 x 7	36	24	1,060	Orbiter (Modification)
FM Signal Processor	SM	1	15	10	19 x 4 x 7	15	10	530	Orbiter
Payload Signal Processor	SM	1	15	10	19 x 4 x 7	15	10	530	Orbiter
Doppler Extractor	SM	2	15	10	19 x 4 x 7	30	20	1,060	Orbiter
Ku-Band RF and Processor									
Electrical Assembly	HM	1	142	300	19 x 15 x 7	142	300	2,000	Orbiter (Modification)
Signal Processor	HM	1	18	8	19 x 5 x 7	18	8	660	Orbiter (Modification)
Internal Communications									
Audio Communication Control Unit	SM	1	9	11	19 x 4 x 7	9	11	530	Orbiter
Audio Terminal Units	HM	1	4	2	19 x 3 x 7	4	2	400	Orbiter
	HM	3	4	2	19 x 3 x 7	12	6	1,197	
	PM	1	4	2	19 x 3 x 7	4	2	399	
	LM	1	4	2	19 x 3 x 7	4	2	400	

*100 W while switching

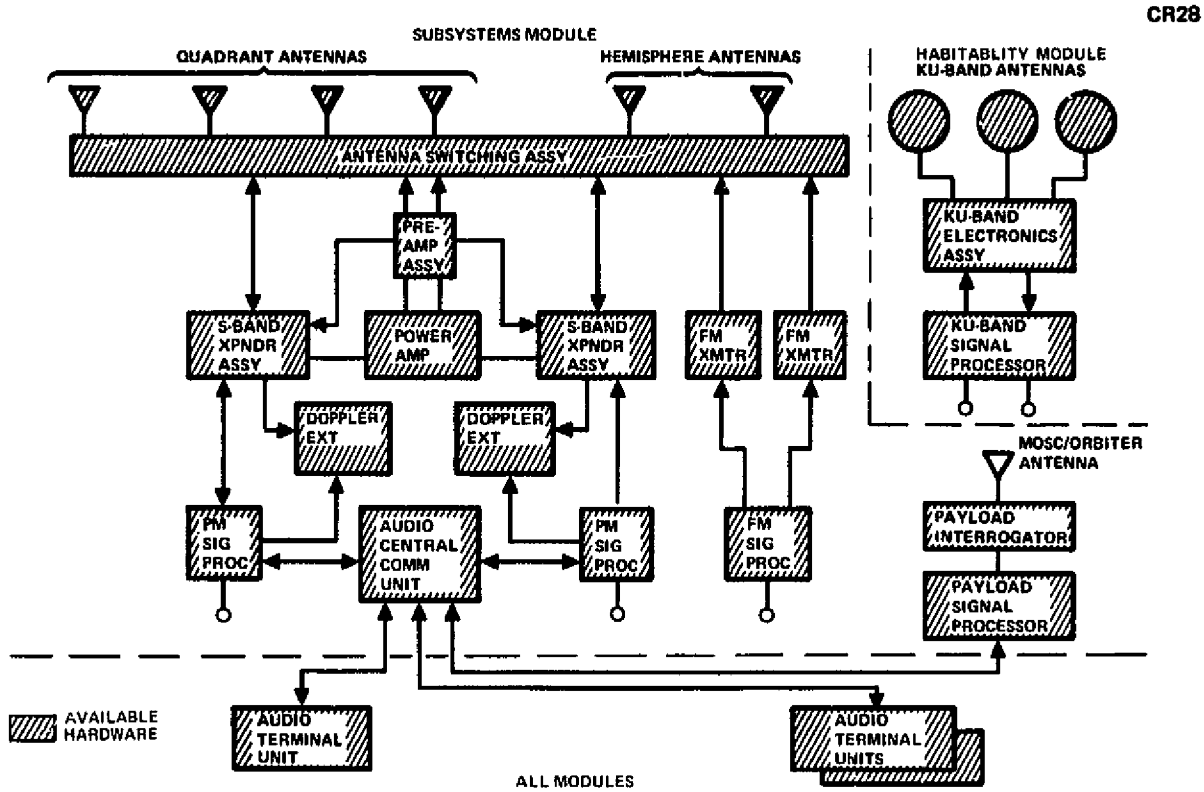


Figure 5-37. Communications Subsystem — Block Diagram

is also available. Baseband data on reception will consist of 216 kbps in the TDRS mode and 72 kbps in the STDN mode. Provisions for space ground link subsystem compatibility will be removed from all units.

The FM system, consisting of redundant transmitters and a signal processor, provides a wideband communications capability with the ground. Provisions are included for video (4.5 MHz), multiple digital (60, 128, 480, 1024 kbps), and analog (300 kHz to 4 MHz) inputs. Hemisphere antennas are selectable via the antenna switching assembly. Both the FM and PM systems are primarily intended for the transfer of engineering data, although experiment support is certainly feasible.

The Ku-band single access system is provided for experiment data transfer. The Orbiter signal processor will require modification to permit the transfer of two simultaneous video signals with 4.5-MHz bandwidths. Data rates to 50 Mbps will be provided on a time-shared basis. Three Orbiter 0.6-m (2-foot) antennas will be utilized, together with booms and boom-mounted preamplifiers. Booms will be extended to allow antenna to be nested between the SM and HM when the MOSC is mounted in the Orbiter cargo bay.

The Orbiter's payload interrogator and signal processor will be used to provide command and engineering data transfer during the premanning phase, and for voice communications between the MOSC and Orbiter thereafter. Twenty channels are available on transmit and receive, capable of 40 kbps (8 kbps command, 32 kbps voice) in the transmit mode and 48 kbps (16 kbps telemetry, 32 kbps voice) in the receive mode.

Communications subsystem performance is summarized in Table 5-17.

5.2.6 Data Management Subsystem

The processing requirements for definition of the experiment data management subsystem are shown in Table 5-18. The major requirements, assuming simultaneous experiment operation, are seen to be: rapid access memory, 6.5E4 words; bulk memory, 5E7 words, and speed (operations/second), 1E6 words.

Table 5-17

COMMUNICATIONS SUBSYSTEM PERFORMANCE CHARACTERISTICS

1.	S-Band/Ground	• Reception/detection of 216 kbps, 72 kbps • Transmission of 192 kbps, 240 kbps, 576 kbps • Duplex RF operation with coherent frequency turnaround ratio of 240/221 • Doppler extraction • Noncoherent RF transmission • Tone ranging turnaround
2.	S-Band/Satellite	• Receive and transmit at one each of 20 channels • Provide full duplex communications (32 kbps voice, 6.4 kbps command transmit; 16 kbps data, 32 kbps voice receive)
3.	Ku-Band/TDRS	• Provide continuous transmission capability over 85 percent of orbit • Transmit data at a 50 Mbps rate • Simultaneously transmit two TV channels

Table 5-18

EXPERIMENT REQUIREMENTS FOR COMPUTER PROCESSING

MOSC Payload Group No.	Rapid Access Memory (words)	Bulk Memory (words)	Speed (ops/sec)
C-01	1.6E4 (8E3)	5E6	1E5 (5E4)
C-02	2.4E4 (8E3)	2E6	1.12E5 (5E4)
C-03	TBD	TBD	TBD
C-04	TBD	TBD	TBD
C-05	1.1E4 (9E3)	1.2E5	3.4E4 (3E4)
C-06	TBD	TBD	TBD
C-07	TBD	TBD	TBD
C-08	TBD	TBD	TBD
C-09	6.5E3 (3.5E3)	7E5	1.2E5 (7E4)
C-10	9.2E3 (3.5E3)	2.1E2	1E5 (3E4)
C-11	TBD (4E3)	TBD	TBD (4E3)
C-12	2E4 (2.4E4)	5E7*	1E6 (5E5)*
C-13	2E4 (2.4E4)	5E7	1E6 (5E5)*
C-14	6.5E4*	1E6	1E5
C-15	1.6E4	1E6	1E5
C-16	TBD	TBD	TBD
C-17	TBD	TBD	TBD
C-18	N/A	N/A	N/A
C-19	TBD	TBD	TBD

( ) Equivalent 32 bit words

* Maximum single (serial) requirement

The recording requirements are shown in Figure 5-38 and Table 5-19, with the major requirements of 10 Mbps for 12 hours, and 3 channels of video for 8 hours.

Although many concepts may be hypothesized for subsystem data management, the availability of Orbiter systems and software coupled with the reliability afforded by the redundancy embodied in their design and the elimination of

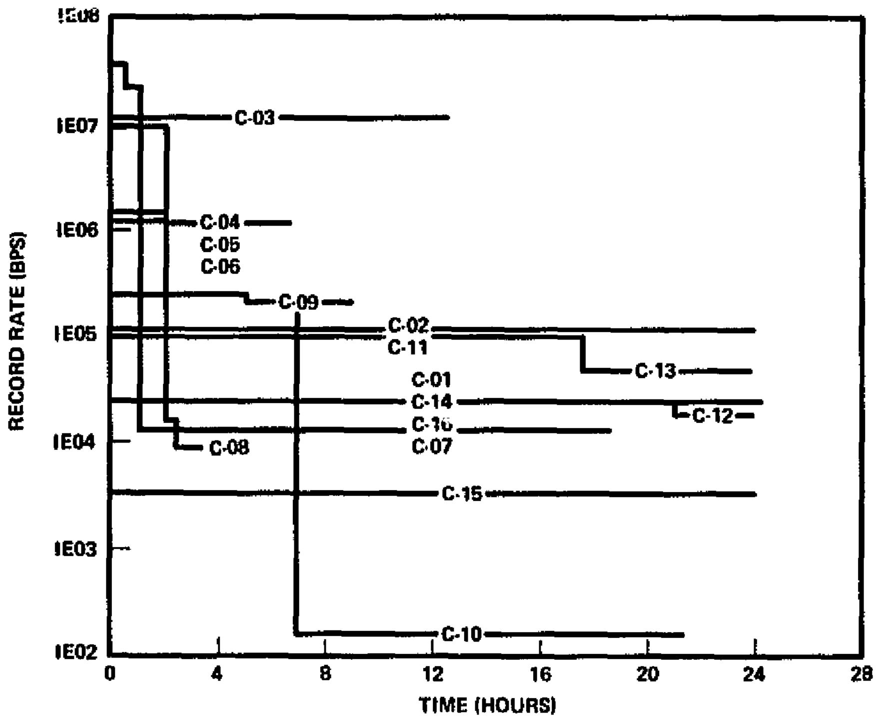


Figure 5-38. Experiment Requirements for Digital Data Storage

development costs makes the selection of any alternate configuration very unattractive. Referring to Figure 5-39, it is readily apparent that the equipment configuration is as suited to MOSC as it is to the Orbiter. Use of Spacelab equipment supporting subsystems was also considered, but it was not adaptable due to emphasis on manual operation. Also, its major functions are data acquisition and display.

Review of the requirements for experiment data management and checkout reveal that rapid access and bulk memory requirements are within the range of existing computers, but that data processing rates, due to experiment grouping, exceed the capabilities of single processors (1,000 versus 400K ops/sec). The alternatives are to centralize the processing in two computers, or use a multiprocessor or a distributed system containing a single processor for centralized control and program storage. The latter concept would use minicomputers dedicated to individual or unique experiment processing tasks, as shown in Figure 5-40. Due to the magnitude of processing requirements, the Spacelab design that is being developed embodying the centralized concept does not have the high capacity required,

Table 5-19

EXPERIMENT REQUIREMENTS FOR ANALOG/VIDEO RECORDING

MOSC Payload Group No.	Analog		Color TV		B/W TV	
	Channels/ Frequency	Hours	Channels	Hours	Channels	Hours/ Channel
C-01	-	-	-	-	2CH	12, 1.6
C-02	-	-	-	-	-	1.5, 1.6 0.24, 1.5
C-03	-	-	-	-	3CH	-
C-04	1CH, 6KHz 1CH, 4MHz	0.5 TBD	-	-	3CH	8.0
C-05	1CH, 5MHz 1CH, 4MHz	0.125 TBD	-	-	3CH	8.0
C-06	TBD 1CH, 4MHz	TBD	TBD	TBD	3CH	8.0
C-07	-	-	-	-	-	-
C-08	2CH, 10MHz	11.8, 2.5	-	-	-	-
C-09	-	-	1CH	TBD	-	-
C-10	-	-	1CH	TBD	-	-
C-11	-	-	-	-	1CH	1.5
C-12	-	-	2CH	TBD	1CH	1.0
C-13	-	-	2CH	TBD	1CH	1.0
C-14	-	-	-	-	1CH	1.5
C-15	-	-	-	-	1CH	1.5
C-16	-	-	TBD	TBD	TBD	TBD
C-17	-	TBD	-	-	-	-
C-18	1CH, 10MHz	3.4	-	-	-	-
C-19	TBD	TBD	TBD	TBD	TBD	TBD

and its input/output unit (I/O) would not support two processors. In addition, the constraints on data acquisition and transfer imposed by the existing I/O, data bus, and remote acquisition unit specifications would result in experiment integration and design problems. Considering the features of the two systems, as presented in Figure 5-40, the distributed system appears to be more suited to a changing experiment environment than does the centralized concept.

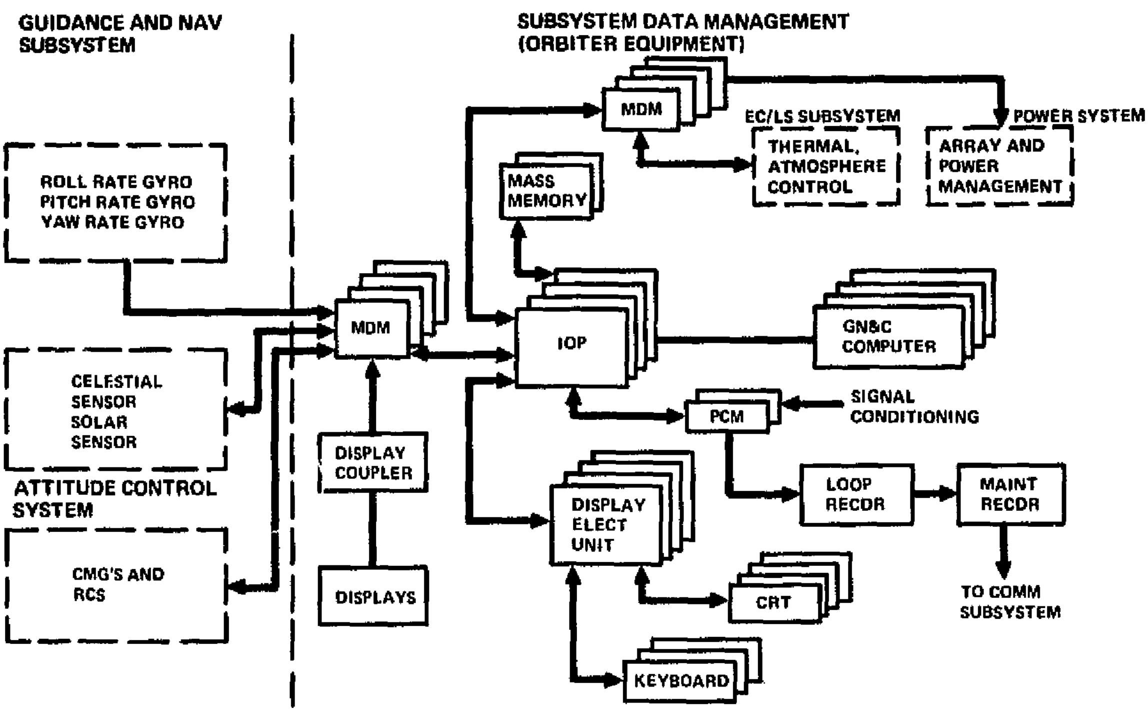
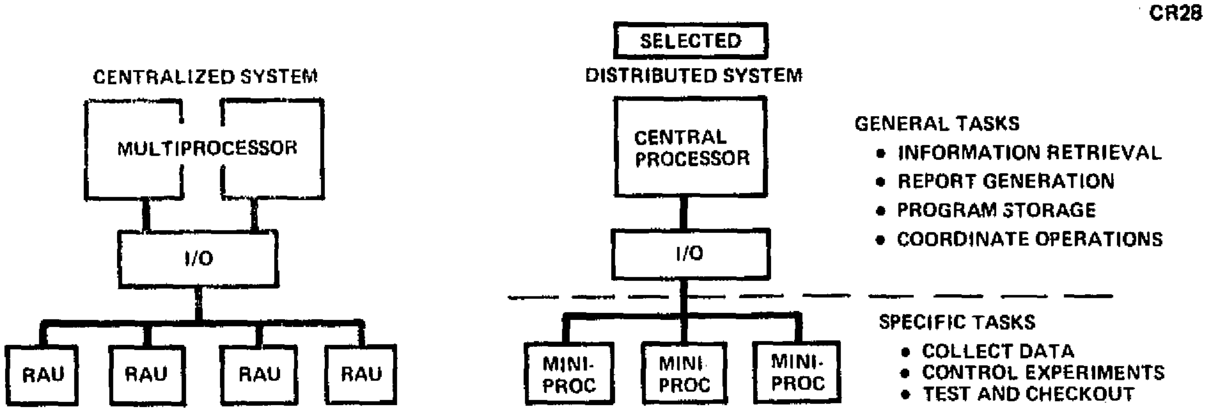


Figure 5-39. Data Management Subsystem Diagram



CONTRASTS

Centralized System	Distributed System
• REQUIRES NEW I/O AND SOFTWARE	• REQUIRES NEW I/O, SOFTWARE, AND SUBSYSTEM DEVELOPMENT
• DATA RATE LIMITED	• PROCESSING RATE/INTERFACE ESTABLISHED BY EXPERIMENT
• GROWTH CONSTRAINED	• GROWTH CONSTRAINED ONLY BY NUMBER OF I/O PORTS
• EXPERIMENT DEVELOPMENT AND INTEGRATION DIFFICULT	• EXPERIMENT/DMS INTERFACE STANDARDIZED; INTEGRATION SIMPLE
• CAPABILITY SET BY MAXIMUM ANTICIPATED LOADING	• CAPABILITY TAILORED TO EXPERIMENT REQUIREMENTS
• MAJOR FUNDING REQUIRED AT BEGINNING OF PROGRAM	• COSTS DISTRIBUTED WITH TIME; BORNE BY EXPERIMENTS

Figure 5-40. Experiment Processing Design Alternatives

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For the remaining function, data storage, the alternatives are whether to provide support for the requirements as listed or to only provide temporary storage; with the availability of continuous data transfer via the TDRS, the need for storage of the magnitudes indicated should be subjected to detail analysis. This is particularly true when comparison of the rates for real-time data transfer and storage are the same, suggesting similarity of material. Furthermore, at the rates shown, the magnitude of recording tapes required for a 60- to 90-day mission would constitute a storage and handling problem of some magnitude. It is recommended that only temporary storage of data using Spacelab 30-Mbps and 6-MHz recorders be contemplated.

5.2.6.1 Baseline Subsystem Description

The data management subsystem is composed of the equipment categories listed in Table 5-20. It is divided into subsystems and experiment categories due to the nature of the equipment available and the difference between subsystem and experiment processing requirements. As illustrated by the source column in the figure, almost all subsystem equipment is available from the Orbiter program. This is further amplified by Figure 5-41, which shows the portion of the data management subsystem dedicated to vehicle support. This portion is identical to the Orbiter basic configuration, with the exception that some standby redundancy has been eliminated along with those systems provided for the ascent and descent portions of the mission.

For subsystem support, data management is seen to include data acquisition equipment consisting of multiplex/demultiplex (MDM) and PCM units. These, in turn, channel engineering data to the general-purpose processor via the data adapter (input/output processor). Inasmuch as the function of the subsystem (excluding guidance, navigation, attitude, and power control functions) is to perform subsystem monitoring via limit checking, standby redundancy switching, and resource management, no mass memory appears to be needed.

The standard multipurpose CRT is provided for format storage and data display. The maintenance and loop recorder concept of the Orbiter is retained to record anomalies and/or malfunctions for later transfer to the ground. Fixes would be incorporated in replacement units transferred to orbit by the logistics module. The caution and warning system is included in its entirety, as is the closed-circuit TV for monitoring external operations.

Table 5-20

DATA MANAGEMENT SUBSYSTEMS EQUIPMENT LIST

Equipment Category	Location	Quantity	Weight (lb)	Power (W)	Dimensions (in.)	Total Weight (lb)	Total Power (W)	Total Volume (in.^{3})	Source
Subsystem Data Processing									
Speech Synthesizer	SM	1	4	10	6 x 4 x 3	Configuration Variable			New
Computer	SM	2	59	337	19 x 10 x 7	118	337	3,000	Orbiter
Data Adapter	SM	2	59	300	19 x 10 x 7	118	300	3,000	Orbiter (Modified)
C & W Logic Unit	SM	1	22	30	19 x 4 x 7	22	30	530	Orbiter
PCM Unit	SM	2	30	30	19 x 5 x 7	60	60	1,320	Orbiter
Mux/Demux	SM	4	30	30	13 x 10 x 7	120	120	3,640	Orbiter
	HM	2				60	60	1,820	
Loop Recorder	SM	1	30	45	10 x 4 x 7	30	45	280	Orbiter
Maint. Recorder	SM	1	45	60	16 x 14 x 7	45	60	1,590	Orbiter
Timing Unit	SM	1	26	30	19 x 10 x 7	26	30	1,330	Orbiter
Master Alarm Unit	SM	1	10	15	7 x 4 x 7	10	15	196	Orbiter
Video Switching Unit	SM	1	5	N/A	7 x 4 x 3	5	NA	84	Orbiter
Subsystem Instrumentation	HM	1							
TV Cameras	SM	1	2	20	2-in. Dia.	2	20	31	Orbiter
	HM	3			10-in. Length	2	20	30	
Signal Conditioning	SM	6	30	40	13 x 10 x 7	180	240	5,460	Orbiter (Modified)
						90	120	2,730	
Transducers	SM	200	0.4	N/A	2-in. Dia.	80	NA	NA	Off Shelf
	HM	100			2-in. Length	40	NA	NA	
Subsystem Display/Control									
Mission Timer	SM	1	8	10	19 x 5 x 4	8	10	400	Orbiter
Event Timer	SM	2	4	8	6 x 5 x 3	8	16	180	Orbiter
CRT/Keyboard	SM	1	50	120	19 x 15 x 12	50	120	3,400	Orbiter
Display Processor	SM	1	60	84	19 x 10 x 7	60	84	1,330	Orbiter
Remote Control/Display	HM	1	60	120	19 x 10 x 7	Configuration Variable			New
C & W Annunciator Assy.	SM	1	6	15	6.8x4x3.9	6	15	112	Orbiter
	HM	1				6	15	112	
Computer Service Panel	SM	1	24	30	19 x 4 x 7	24	30	532	Orbiter
Teletype	SM	1	15	15	12 x 6 x 6	15	15	432	Orbiter
Video Monitor	SM	1	35	60	19 x 13 x 14	35	60	3,700	Orbiter
Discrete Control/ Display Panels	SM	4	75	15	19 x 3 x 7	300	60	1,600	New
Experiment Data Processing									
Speech Synchesizer	HM	1	4	10	6 x 4 x 3	Configuration Variable			New
Comm. Processor	HM	1	35	115	19 x 8 x 7	35	115	1,056	Off Shelf
Input/Output Unit	HM	1	20	45	19 x 8 x 5	20	45	750	New
Mass Memory	HM	1	45	60	16 x 14 x 7	45	60	1,590	Orbiter
Exper. Processor	HM	1	3	13	4 x 4 x 3	Configuration Variable			Off Shelf
	PM	2							
Digital Recorder (Low Rate)	HM	1	45	60	16 x 14 x 7	45	60	1,590	New
Digital Recorder (Hi Rate)	HM	1	100	367	19 x 18 x 12	100	367	4,100	Spacelab
Video Recorder	HM	2	70	200	19 x 18 x 7	Configuration Variable			Spacelab
Digital Multiplexer	HM	1	15	20	13 x 5 x 7	Configuration Variable			Spacelab
Analog Multiplexer	HM	1	30	30	19 x 10 x 7	Configuration Variable			New
Analog to Digital Converter	HM	1	15	20	13 x 5 x 7	Configuration Variable			New
Fault Logic Unit	HM	1	15	20	13 x 5 x 7	Configuration Variable			New
	PM	1							
Scan Converter	PM	0	198	300	13 x 13 x 30	Configuration Variable			New
Video Switching Unit	HM	1	6	N/A	19 x 3 x 3.5	6	N/A	200	Orbiter
Experiment Display/Control									
CRT/Keyboard	HM	1	50	120	19 x 15 x 12	50	120	3,400	Orbiter
Mission Timer	HM	2	8	10	19 x 5 x 4	16	20	800	Orbiter
	PM	2				Configuration Variable			
Event Timer	HM	1	4	8	6 x 5 x 3	4	8	90	Orbiter
	PM	2				Configuration Variable			
Display Processor	HM	1	60	84	19 x 10 x 7	60	84	1,330	Orbiter
Computer Serv. Panel	HM	1	24	30	19 x 4 x 7	24	30	530	New
Video Monitor	HM	2	35	60	19 x 13 x 14	Configuration Variable			Orbiter
Oscillograph	PM	1	28	40	19 x 13 x 7	Configuration Variable			New
X-Y Plotter	PM	1	35	60	19 x 13 x 14	Configuration Variable			New
Microfilm Unit	PM	1	60	20	19 x 19 x 28	Configuration Variable			New
Fault Annunciator	HM	1	6	15	7 x 4 x 4	Configuration Variable			New
	PM	1				Configuration Variable			
Remote Control/Display	HM	1	60	120	19 x 10 x 7	60	20	1,330	New
	PM	2				Configuration Variable			

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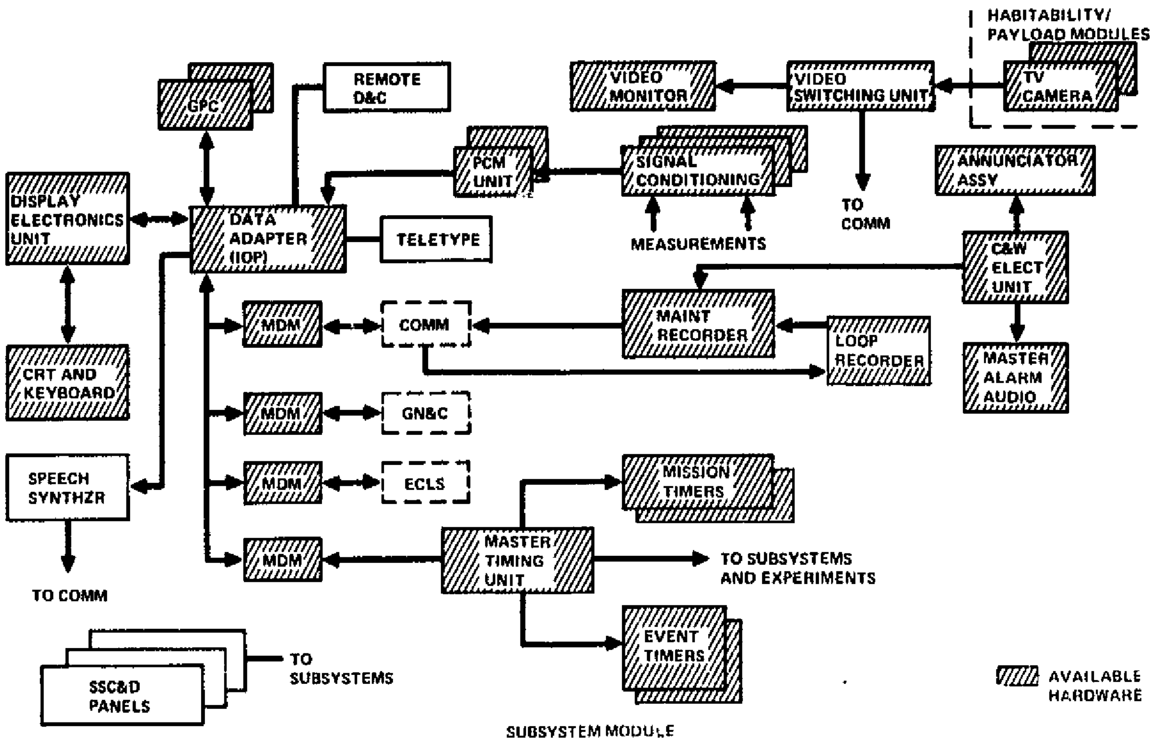

Figure 5-41. Baseline 4-Man MOSC Data Management Subsystem -- Vehicle Support

The experiment portion of the data management system is illustrated in Figure 5-42. While much equipment is retained from the Orbiter and Spacelab programs, such as high rate and analog video recorders, the system represents a marked departure from the large computer baseline previously incorporated in the Space Station Study and in Spacelab. Instead, a central processor is used for communications among a number of small experiment-dedicated computers and some centralized computer peripherals, such as mass memory, displays and printout devices. The advantages of this configuration are as follows: software integration is reduced, system sizing is optimized and total hardware costs are reduced, the experimenter has a computer to use during experiment development and simulation costs are reduced, the computers constitute a part of the experiment and are not chargeable to MOSC, and costs are spread over the life of the program.

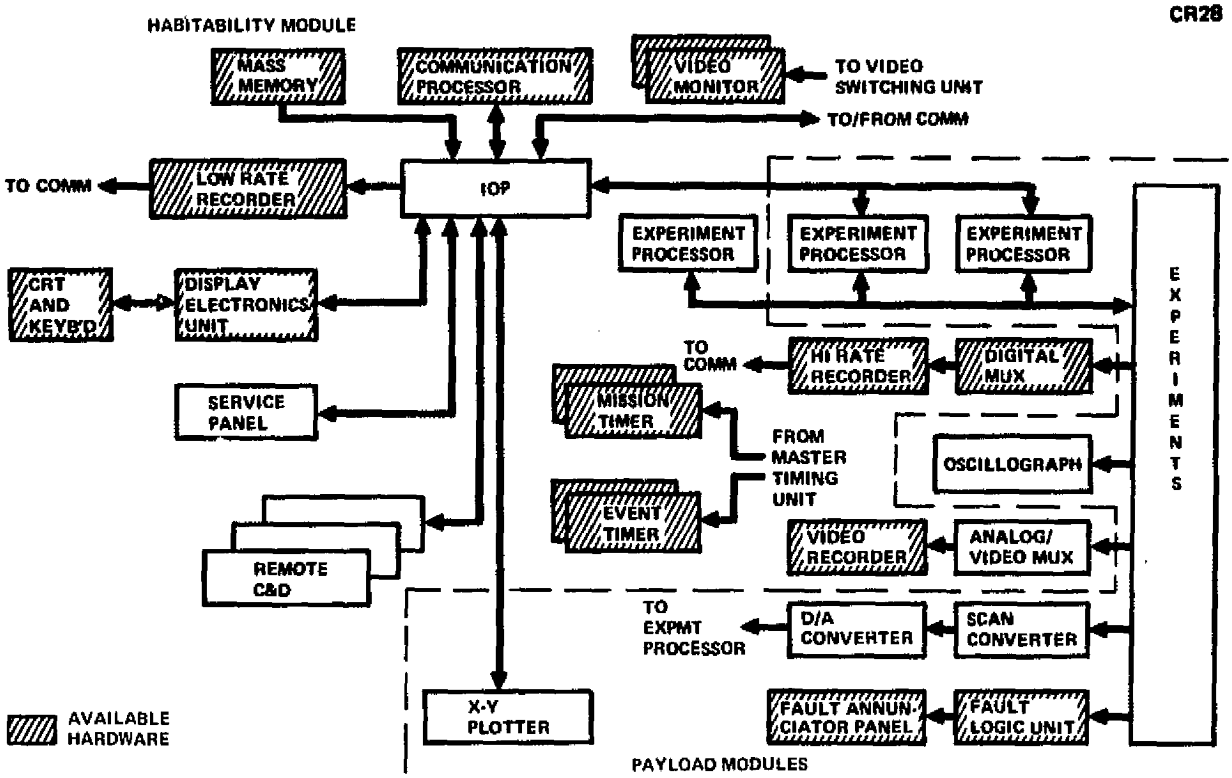

Figure 5-42. Data Management Subsystem — Block Diagram — Experiment Support

In addition to the baseline system, other equipment has been included, such as an oscillograph, X-Y plotter, scan converter, etc., which may or may not be required on every flight and/or which may be included as general purpose equipment in a payload module. Although not included in the basic Spacelab configuration, some equipment such as an analog multiplexer, a digital multiplexer (soon to be incorporated in the Spacelab baseline per NASA/ESRO agreement), and a fault enunciator panel are also provided.

The performance characteristics of data management subsystems are summarized in Table 5-21.

Table 5-21

DATA MANAGEMENT SUBSYSTEM PERFORMANCE CHARACTERISTICS

1.	Subsystems	• Fixed-point, binary fractional • Floating point, hexadecimal fraction • Addressing modes: base plus displacement, indexed, indirect, relative, extended, immediate • Asynchronous memory, 800 μsec cycle, 400 μsec access, 36 bit words • Direct memory access to 450K words • 24 serial buses, 1 MHz, Manchester Code • Variable configuration multiplexer interface adapters, sequence control units, A/D converters, interface modules, power supplies • Built in test • GMT, MET Clock (IRGIB), 4.608 MHz, 1 kHz, 100 Hz, 10 Hz, 1.0 Hz contingency frequencies • Multifunction CRT and keyboard
2.	Experiments	• Provisions for 6 central computer peripherals • Provisions for 4 satellite computers • 1 Mbps serial data bus rate • 24K word memory (Central Communications Processor) • 16K word memory (Satellite Processors)

5.2.6.2 Subsystem Checkout Concepts

For the communications and subsystem portions of the data management system, the checkout concepts embodied in the Orbiter system designs will obviously hold true for the MOSC, i.e., the degree of self-test embodied in the various units and assemblies will not be changed. However, while fault detection and the automatic or manual selection of backup units may not be pertinent, the degree of fault isolation to be performed by the crew must be considered.

Whether the crew should be involved in the diagnosis of faults within a line replaceable unit (LRU) depends upon the following:

- Can the crew repair the unit?
- Is it a cost-effective use of their time?
- Does it reduce the requirements for ground support?

The answers to these questions cannot be provided until all equipment has been selected and evaluated for real-time repair by the crew. An an initial approach to MOSC planning, it is recommended that repair be limited to the replacement of LRU's.

The alternatives for experiment checkout are as varied as the experiments themselves. Rather than attempt to impose a rigid philosophy, it is suggested that each category be allowed to employ those methods best suited to its particular problem. The flexibility afforded by the distributed processor system allows this method of operation.

5.2.6.3 Recommendations

It is recommended that Orbiter equipment and software be used for subsystem data management and checkout. Experiment data management subsystems should utilize Spacelab high-rate digital and video recorders and whatever supplementary data acquisition and formatting equipment, such as subcarrier/frequency multiplexers and switching units, is suitable. Software modules, written in high-order language, are also directly transferable. The major experiment processing equipment consisting of computers and I/O should be of new design. Peripherals for control, display, and bulk memory may be Orbiter units.

The subsystem checkout features are summarized in Table 5-22.

Table 5-22.
SUBSYSTEM CHECKOUT CHARACTERISTICS SUMMARY

- Automatic fault isolation to the line replaceable unit (LRU)
- Automatic switching to standby unit for critical LRUs within TBD seconds after crew notification of fault
- Manual override for all LRU switching operations
- Failure and trend analysis capability

5.2.7 Stabilization and Control Subsystem

The stabilization and control subsystem (SCS) is used to control the orientation of the MOSC during all phases of orbital operation. This capability starts following placement of the system in orbit by the Orbiter and continues until retrieval docking.

5.2.7.1 Requirements

The attitude pointing and control requirements for the SCS are derived from two basic sources: (1) analysis of the individual experiment requirements for the various payload combinations, and (2) analysis of mission operations.

The subsystem performance requirements for attitude control and attitude determination were derived from the experiment pointing and stability requirements presented in Tables 5-23 and 5-24.

Table 5-23 summarizes pointing requirements for each of the experiment combinations (C-01 through C-19), assuming a single payload combination for each mission. Table 5-24 presents the same kind of data for experiment packages reorganized into preferred orbit inclinations. These tables also provide preliminary estimates of the attitude pointing and control modes required to provide the desired experiment pointing. In general, the stellar- and solar-oriented experiments require the most precise pointing accuracy (1 to 5 arc-sec), while the Earth-pointing types require less precision (1,800 arc-sec). Coarse pointing of the stellar/solar experiments is accomplished by pointing the cluster in response to the error signal

Table 5-23

MOSC PAYLOAD COMBINATION REQUIREMENTS

Payload Combination	Orientation	Mission Duration (days)	Experiment Pointing and Stability Requirements: Pointing Accuracy (sec)	Pointing Stability (sec)	Rate Stability (sec/sec)	Subsystems Module Att. Ref. Sensor	Subsystems Module Control System	Subsystems Module Pointing Accuracy (sec)	Experiment Pointing: Sensor	Control
C-01	Stellar	40	5	1	0.1	Celestial	CMG	20-40	Celestial	Gimbal Torquer
C-02	Stellar	70	1	1	0.1	Celestial	CMG	20-40	Celestial	Gimbal Torquer
C-03	Solar	40	1	0.5	0.0011	Sun	CMG	20-40	Sun	Gimbal Torquer
C-04	Earth	35	1,800	360	180	Horizon	Jets	900	None	None
C-05	Earth	40	1,800	360	180	Horizon	Jets	900	None	None
C-06	Earth	60	1,800	360	360	Horizon	Jets	900	None	None
C-07	Any	40	1,800	360	360	-	Jets	900	None	None
C-08	Earth	50	1,800	1,800	360	Horizon	Jets	900	None	None
C-09	Earth	25	1,800	900	1,080	Horizon	Jets	900	None	None
C-10	Earth	40	1,800	360	72	Horizon	Jets	900	None	None
C-11	Stellar	35	5	0.3	1	Celestial	CMG	20-40	Celestial	Gimbal Torquer
C-12	Any	100	NA	NA	NA	-	-	--	-	-
C-13	Any	100	NA	NA	NA	-	-	--	-	-
C-14	Stellar	25	1	1	0.1	Celestial	CMG	20-40	Celestial	Gimbal Torquer
C-15	Stellar	60	1	1	0.1	Celestial	CMG	20-40	Celestial	Gimbal Torquer
C-16	Stellar	300	NA	NA	NA	Celestial	CMG	--	None	None
C-17	Any	>360	NA	NA	NA	-	CMG	--	-	-
C-18	Earth/ Stellar	30	1,800	720	360	Horizon/ Celestial	Jets	900	None	None
C-19	Solar	>720	-	-	-	-	CMG	--	-	-

Table 5-24

ATTITUDE AND POINTING CONTROL SUBSYSTEM SUMMARY
FOR PRIMARY ORBIT INCLINATIONS

			Experiment Pointing and Stabilization Requirements			Subsystems Mod. Att. Control and Stabilization			Experiment Pointing and Control	
Inclination	Payload Combination Number	Orientation	Pointing Acc. (sec)	Pointing Stab. (sec)	Rate Stab. (sec/sec)	Att. Ref. Sensor	Stabilization and Control	Pointing Accuracy (sec)	Sensor	Control
28.5°	C-01 C-02 C-11	Stellar	1	1	0.1	Celestial	CMG	20-40	Fine Guid.	Torq/Flex Pivot
	C-08	Earth	1,800	1,800	360	Horizon	Jets	900	NA	NA
	C-03	Solar	1	0.5	0.0011	Sun	CMG	20-40	Fine Guid.	Torq/Flex Pivot
	C-07* C-12 C-13	Any of Above	1,800	360	360	Any of Above	Any of Above	900	NA	NA
Polar	C-04 C-05 C-06 C-09 C-10 C-18	Earth	1,800	360	72	Horizon	Jets	900	NA	NA
	C-14 C-15	Stellar	1	1	0.1	Celestial	CMG	20-40	Fine Guid.	Torq/Flex Pivot

*Experiment pointing requirements apply only to C-07

NOTE: Not included in the Attitude and Pointing Summary are the C-16 and C-17 long-duration ≥360-day missions accomplished in the 28.5° inclined orbit and C-19, a >720-day polar orbit payload. These experiments are not sensitive to vehicle pointing accuracy.

information generated by the coarse pointing celestial sensors. Fine pointing of the experiment by means of a two-axis flexure gimbal system, as indicated in Figure 5-43, is then required to meet the pointing accuracy and stability requirements of the particular experiment combination. The pointing requirements of the Earth experiments can be met by controlling the attitude of the MOSC in response to the error signals generated by the Earth sensor, e.g., horizon sensor, together with precision alignment of the experiment with the attitude reference base.

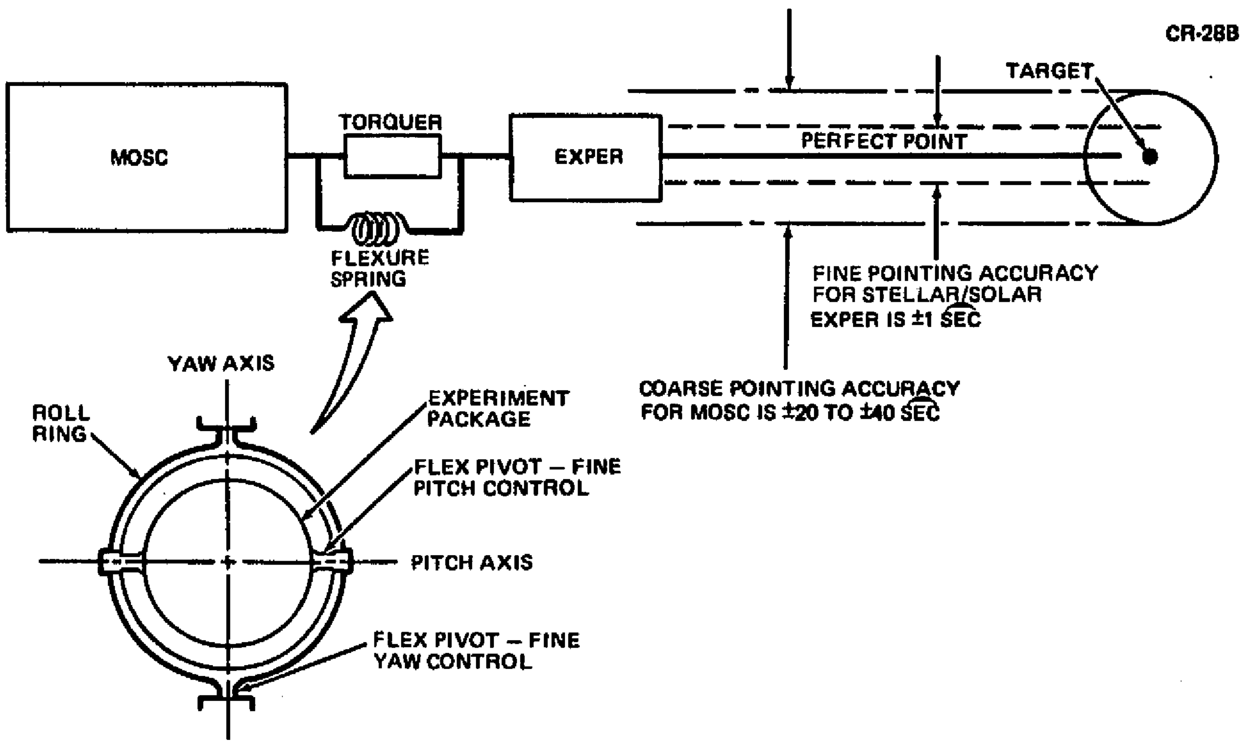

Figure 5-43. Stellar/Solar Experiment Pointing Concept

5.2.7.2 Candidate Concepts

Table 5-25 presents a summary of the reference sensors and attitude stabilization and control concepts required for the MOSC missions. For comparison purposes the present Spacelab pointing and control schemes are also shown. Spacelab experiment pointing concepts revolve around three classes of experiments. Those requiring the most precision pointing rely on the ESRO instrument pointing system and either pallet-mounted CMG's or Orbiter VCS stabilization, depending on the experiment pointing requirements. Other less sensitive payloads require a pallet-mounted inertial measurement unit (IMU) and appropriate attitude sensors interfaced with the Orbiter flight control system to obtain the desired pointing.

Table 5-25

POINTING SUBSYSTEM COMPARISON AND DESIGN RECOMMENDATION

System		Reference Sensors: Orbiter IMU	IMU	Solar	Celestial	Earth	Attitude Stabilization & Control: Orbiter VCS	Jets	CMG	Remarks
Spacelab	Pallet Mt'd		X		X	X	X			Orbit. Ref Platform Replaced by Pallet Mounted IMU & Ref. Sensors
	ESRO IPS Mt'd	X			X		X			Celestial Sensor & Gimbal Torquer of IPS Provides P'ting of 1 Sec (Orbiter Coarse P'ting)
	ESRO IPS Mtd-CMG	X		X	X				X	CMG Stabilization of Pallet Mounted Payloads and Additional Internal Pointing Capability Required
MOSC Payloads C-01 to C-19			X	X	X	X		X[1]	X	SM Provides Earth P'ting and Coarse P'ting for Stellar/Solar Orient. Stellar and Solar Exp. Require Fine P'ting and Control
Orbit Requirements										
28.5° Inclination			X	X	X	X		X[1]	X	
Polar Inclination			X		X	X		X[1]	X	
MOSC Design Recommendation			X	X	X	X		X[1]	X	

- Cluster Pointing (HM, SM, PM)
  - Stellar & Solar 20-40 Sec
  - Earth 900 Sec
- Experiments Pointing W/Fine Guidance Sensor & Control ≤1 Sec

[1] Thrusters are for backup and to control docking disturbance

The MOSC pointing systems all require autonomous attitude pointing and control and various combinations of reference sensors and means of stabilization, depending on the payload involved. A single system offering a unified design approach, capable of satisfying any experiment combination, is proposed for the initial MOSC concept.

5.2.7.3 Recommendations

The design recommendation incorporates an integrated attitude reference capability together with CMG and reaction jet stabilization and control. CMG's were selected over thrusters as the primary means of attitude control from consideration of (1) experiment pointing stability and rate stability requirements, (2) desire to eliminate a source of experiment and sensor contamination, and (3) mission durations of from 90 days to 2 years. Thrusters are included only to provide backup and to control vehicle disturbances during Orbiter dockings and orbit-keeping maneuvers.

5.2.7.4 Baseline Subsystem Description

A block diagram of the recommended system is shown in Figure 5-44. The attitude reference sensors provided are responsive to stellar, solar, and Earth pointing. An onboard computer accepts inputs from these sensors through a digital interface for use in celestial coordinate and solar coordinate computations for the stellar inertial and solar inertial orientations, respectively, and provides gyrocompass loop computations to provide attitude reference determination during periods of star occulation and/or orbit nighttime. CMG's are used as the primary controllers, and they rely on computer computation of control commands and momentum management. Also shown in Figure 5-44 is a block diagram of the experiment fine pointing system. This system uses fine guidance sensors and rate gyros as the primary sensors for fine pointing of the stellar/solar experiments. A two-axis flexure gimbal system (see Figure 5-43) is provided to meet the experiment pointing and rate stability requirements. A gimbal ring, which includes flex pivots and torquers in the pitch and yaw axes, will be used to support the experiment package. This will isolate the experiment from MOSC mating, except for disturbances transmitted by the spring rate of the flex pivots and electrical wires and by center-of-gravity offset from the pivot because of tolerances. Signals from the experiment fine guidance

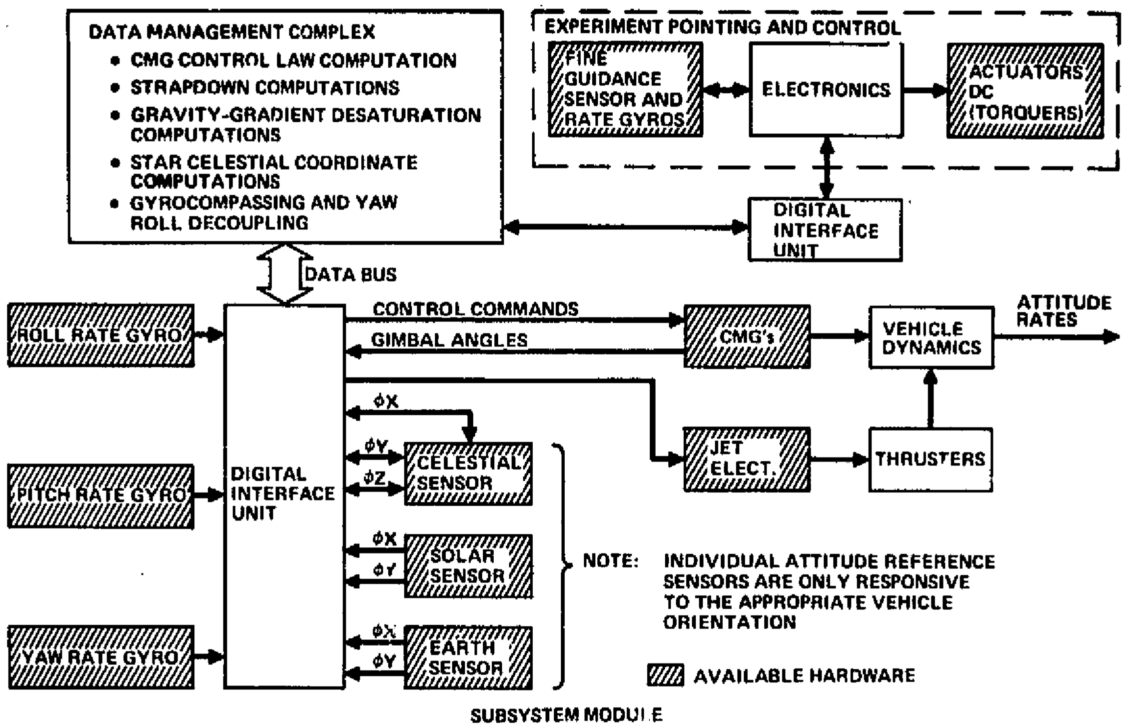

Figure 5-44. Baseline 4-Man MOSC Stabilization and Control Subsystem Diagram

sensor and rate gyros will be processed in the electronics assembly, which transmits torquing currents to the pitch and yaw torquers. A roll ring can be provided to permit the experiment to be rolled about its line of sight.

Consideration has been given to the use of available hardware to build the proposed SCS. Coarse and fine pointing control system hardware components that meet MOSC requirements are current state of the art, and others will be available after the Spacelab has flown. Some components that have been used on previous NASA programs will also be available in an improved form for the MOSC application. For example, improvements in the Skylab ATM CMG's, which have been demonstrated by MSFC, are attractive for this application and include (1) increased angular momentum and torque, (2) increased reliability, and (3) unlimited gimbal freedom through use of slip rings. This last improvement removes the gimbal stop restraint to continuous Z-LV operations under CMG control. Shuttle Orbiter design and development progress can also be monitored for MOSC applicability. Further attention is given to specific recommendations in this area in the following sections.

Rate and Attitude Sensors

The types of rate and attitude reference sensors evaluated for MOSC included gas-rotor bearing gyros, conical scan and edge tracking horizon sensors and electronics, and gimbaled plan trackers.

Rate Sensors

The type of rate-sensing gyro considered for MOSC application is the single-degree-of-freedom floated gyro. The floated gyro has been developed to a high degree of perfection by quite a number of manufacturers. The unique feature of this design is the buoyant support of the gyroscopic element, together with its gimbal assembly, by a heavy viscous fluid. The gyroscopic element sealed within the cylindrical gimbal spins in a gas, but the fluid surrounds and supports the sealed gimbal cylinder. Gas pressure for suspending the rotor is generated by rotor motion, causing the bearing elements to be separated by a thin film of gas.

Although single-degree-of-freedom floated gyros are made with rotor bearings other than gas bearing, only gas-bearing gyros have suitable performance and life to be candidates for the MOSC attitude reference system.

The type of gas bearing gyro that appears to be the most attractive is the pulse rebalance type of gas-bearing gyro. This gyro is most frequently used when the gyro information is to be processed by a digital computer, since a pulse train is output which can be readily converted to a form compatible with the computer.

For MOSC, it is planned to use nine of these rate gyros — three sets orthogonally mounted in each axis. One pair of gyros in each axis will be operating at any given time, which was the approach used on Skylab. This pair-and-spare technique provides for an automatic failure detection scheme (computer assisted) that ensures uninterrupted rate stabilization of MOSC. For reliability analyses, a life factor of 45,000 hours and MTBF rate of 50,000 hours has been used as typical for this class of gyro.

Earth Sensors

This discussion presents the characteristics of sensors that may be used in the MOSC attitude reference to determine the vehicle roll and pitch attitude relative to the "local vertical." The principal operating mode, when these sensors are in use, is to control attitude to the sensor null, which is coincident with the "local vertical."

The type of Earth sensor considered is the IR horizon sensor. The basic principle of the infrared horizon sensor is that of detecting the IR emission given off by the Earth's disk. From the observation of this emission, the angles between the vehicle roll and pitch axes and the normal to the center of the Earth's disk are determined.

Two types of horizon sensor systems were investigated for use on the MOSC: the conical scan and the edge tracker. The detector field of view and scan pattern associated with these techniques are shown in Figure 5-45.

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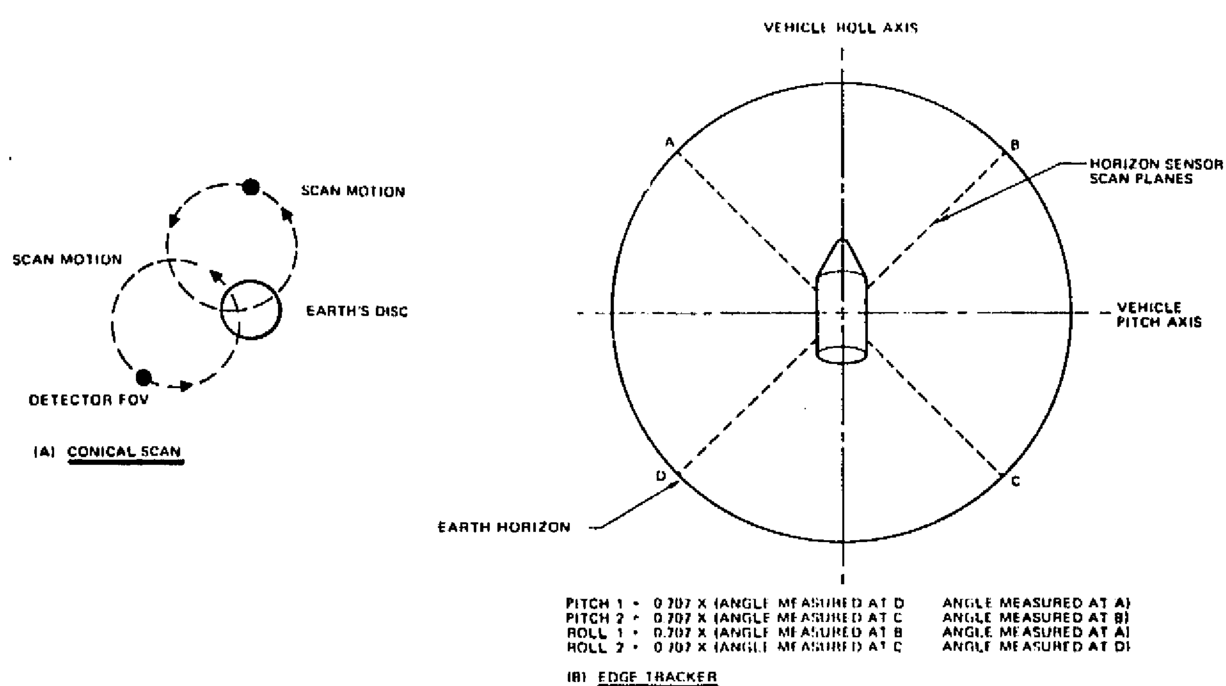

Figure 5-45. Horizon Sensing Techniques

In the conical scan, the instantaneous detector field is relatively small and is caused to scan through a large cone whose apex angle may be as much as 180 degrees, although a more usual apex angle is between 50 and 120°.

Two sensors are used to generate pitch and roll attitude information. The conical-scan-type horizon sensor has a number of very significant advantages. It has excellent acquisition capability as a result of the large conical-scan angle. The attitude information is derived from time characteristics of an amplitude-limited waveshape and therefore is insensitive to radiance variations over the surface of the Earth. Also, since the detector views space during some part of the large scan, this provides an absolute-zero radiance level for calibration and for setting levels to discriminate against radiance discontinuities that occur over the Earth's disk, such as clouds and the terminator.

The primary disadvantage of the conical scan sensor, which is highly undesirable for MOSC, is the need for rotating elements that present life and lubrication difficulties in space applications.

The basic concept of the edge tracking sensor is indicated in Figure 5-45. This sketch represents a view of the Earth horizon and the spacecraft as seen from above the vehicle. Spacecraft pitch and roll can be computed from any of three independent measurements of the angle between the vehicle axes and a line of sight to the horizon.

Although three measurements are normally required, four points on the horizon are tracked to allow undegraded operation with the sun on the horizon and to introduce redundancy into the system for improved reliability.

As shown in the figure, each tracker makes one measurement of the angle between the line of sight to the horizon and the vehicle yaw axis as measured in a vertical plane. The four tracking planes are spaced 90 degrees apart in azimuth and are skewed 45 degrees relative to the vehicle pitch and roll axes.

Each of the four trackers supplies digital horizon angle information to the horizon sensor electronics assembly. Digital circuitry within this assembly calculates two independent values of pitch and two independent values of roll continuously according to the equations noted on Figure 5-45. Each tracker also supplies the vehicle with two logic signals. One of these signals indicates the presence of the sun in that tracker field of view; the other, the alarm signal, indicates whether the tracker is properly locked on the Earth.

Star Trackers

Star trackers considered for use on MOSC include both electronic and mechanical scanning instruments.

The electronic star trackers are attractive because of their light weight and high reliability. The present state of the art in electronic star trackers results in an accuracy of 0.1 percent of the total field of view. Therefore, in order to obtain the type of accuracies required for MOSC, a narrow field of view is required. As the field of view (FOV) is reduced, however, the probability that a star will be within the tracker's FOV is also reduced. In order to meet the MOSC accuracy requirements, a FOV of less than 10° would be required. With a FOV this small, it will be necessary to utilize multiple sensors to obtain a reasonable probability that a detectable star will be within the FOV of the sensor. Utilization of six electronic star trackers provides reasonable capability for inertial orientation with minimal impact on operational flexibility.

Gimbaled star trackers have been utilized in a number of space applications and space-qualified devices are available from a number of manufacturers. The advantages of these devices are their accuracy, the large gimbal freedom which lends flexibility to the attitude determination for any vehicle orientation, and their proven design. The basic tradeoff between the gimbaled star tracker and the electronic trackers is one of accuracy and flexibility versus reliability and weight. For the MOSC application, which permits regular orbital maintenance, the gimbaled star tracker advantages appear to outweigh those of the electronic type.

Control Moment Gyro Stabilization and Control System

As a basis for comparison, the available CMG systems were sized to provide a minimum angular momentum capability of 8,000 ft-lb-sec broken down as follows: (1) 2,500 ft-lb-sec were allocated for the worst-case gravity gradient: cyclic torques during one orbit, (2) 5,500 ft-lb-sec to accommodate Z-LV maneuvers (nominal maneuver rate of 0.1 deg/sec), orbit rate initiation for Z-LV experiment operations (0.066 deg/sec), and gravity bias torque accommodation during solar inertial operation. No allocation for venting torques was required, due to the absence of water vapor venting. Leakage torques were assumed negligible.

The CMG's that are available for use in the MOSC system are the Skylab ATM CMG, the improved 2000H CMG, and the 6000H CMG, reference Table 5-26. Of these, only the latter two are applicable. The ATM CMG has not been considered a serious candidate because the present reliability estimates and operational constraints make it unattractive for long-duration missions.

ATM CMG gimbal stops present a physical restraint to continuous Z-LV operations in some CMG orientations unless designed for nested operation. Auxiliary propulsion system plus CMG's were used.

Table 5-25 compares the features of the improved 2000H and 6000H CMG's. ATM CMG data are included for reference purposes. For normal operation three improved 2000H CMG's were needed to meet the 8,000-ft-lb-sec capacity, while two of the 6000H CMG's provide more than twice that required (two CMG's are needed for three-axis control). CMG improvements, incorporated in the 2000H and 6000H systems, that are attractive for MOSC missions include: (1) three-year life without repair, (2) increased angular momentum and torque, (3) unlimited gimbal freedom through use of slip rings, and (4) all the above through use of state-of-the-art hardware. Of the two candidates, the 6000H system appears the best choice for MOSC. This conclusion is based on (1) performance, (2) control margin, (3) greater flexibility in performing mission objectives, and (4) vehicle CMG accommodation.

Table 5-26

CMG COMPARISON SUMMARY

Comparison Criteria	Present ATM CMG	Improved 2000H CMG	6000H CMG
Total No. Needed for 8000 ft-lb-sec capacity	4	3	2
Weight of Each CMG, lb	420	420	650
Volume Envelope of Each, inches	39x40x39	42x43x40	49x49x40
Steady State Power Power (each) watts	40	30	60
Run Up Time, hrs	14	2	8
Mounting Provisions	Each operating set orthog. mtd; gimbaled mtg req'd for spares	Unlimited gimbal freedom-slip rings	Unlimited gimbal freedom-slip rings
Vehicle Orientation Limitations	Z-LV capacity limited by gimbal stops	None	None
Growth Capability	Negligible	Small	Large
Max Angular Momentum (each), ft-lb-sec	2,300	3,000	9,000
Qualification Status	Flight Proven	Qualified in Ground Test - 1972	Ground Development Testing - 1973

Attitude Reference System Baseline Approach

During MOSC orbital operations, the attitude reference must provide attitude and rate relative to Earth-centered coordinates, inertial coordinates, and stellar coordinates to support experiments, navigation, and attitude control. A functional block diagram of the attitude reference configuration selected to provide these functions is shown in Figure 5-46 as an overview of the general organization of the attitude control system for the MOSC.

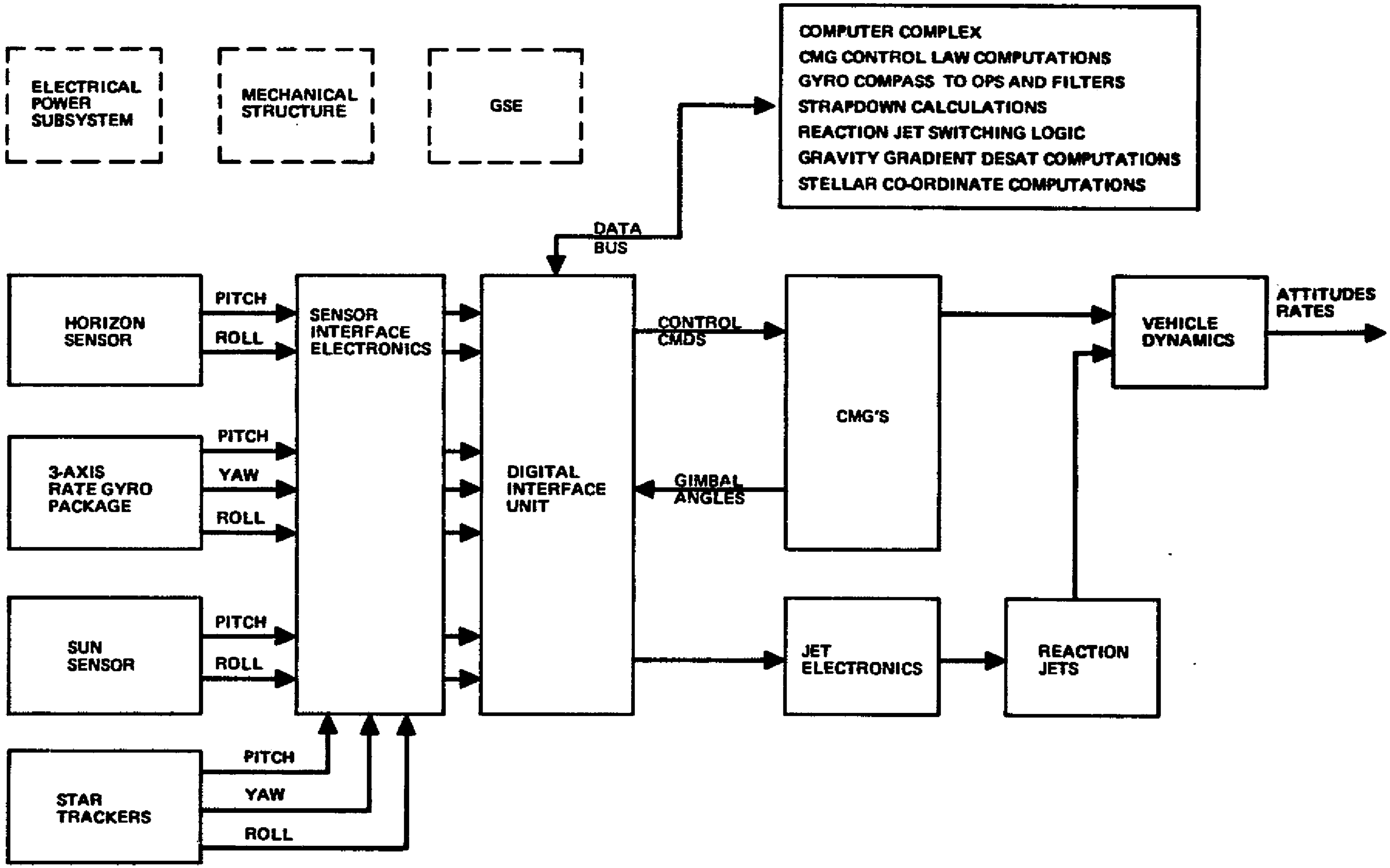

Figure 5-46. General Organization of Stabilization and Control System

The sensors that provide the basic information for determination of the vehicle attitude are shown on the left and include the horizon sensor, strap-down gyro package star trackers, and acquisition sun sensors. The three small dotted blocks at the top of the diagram represent and are a recognition of the interface that must exist between the stabilization and control system and the electrical, mechanical, and GSE systems, without establishing the detailed interface requirements. The selected system is most responsive to the three principal orientations: local vertical/orbit plane (Z-LV), solar inertial, and stellar.

In the local vertical orientation, an Earth-centered reference is directly obtained by means of a vertical sensor such as the horizon sensor. Since only the two axes (pitch and roll) information is obtained from this device, it is necessary to utilize the strapdown gyro package and roll horizon sensor to obtain azimuth data indirectly by means of gyrocompassing. This combination of sensors also provides the capability of acquiring the horizontal orientation from an unknown random orientation. The stabilization and control system configuration for the local vertical mode is shown in Figure 5-47.

The solar inertial mode depends on the acquisition sun sensor as the pitch and roll reference sensor during the daylight portion of the orbit. Orbital nighttime reference signals for these axes are obtained from strapdown calculations using rate gyro input data. The yaw attitude reference signal is provided solely from strapdown calculations and as such is subject to gyro drift error, which must be corrected periodically. This update can be accomplished by using the yaw reference available when the vehicle is in the Z-LV orientation or more directly through use of the star tracker reference. Because the gas-bearing rate gyros have very low random drift (approximately 0.1°/hr) the update frequency can be rather low, except when a precise solar inertial reference is required for experiment operations. The attitude reference configuration for the solar inertial mode is shown in Figure 5-48. Rate information for both attitude control and experiment support is obtained by proper processing of the gyro signals.

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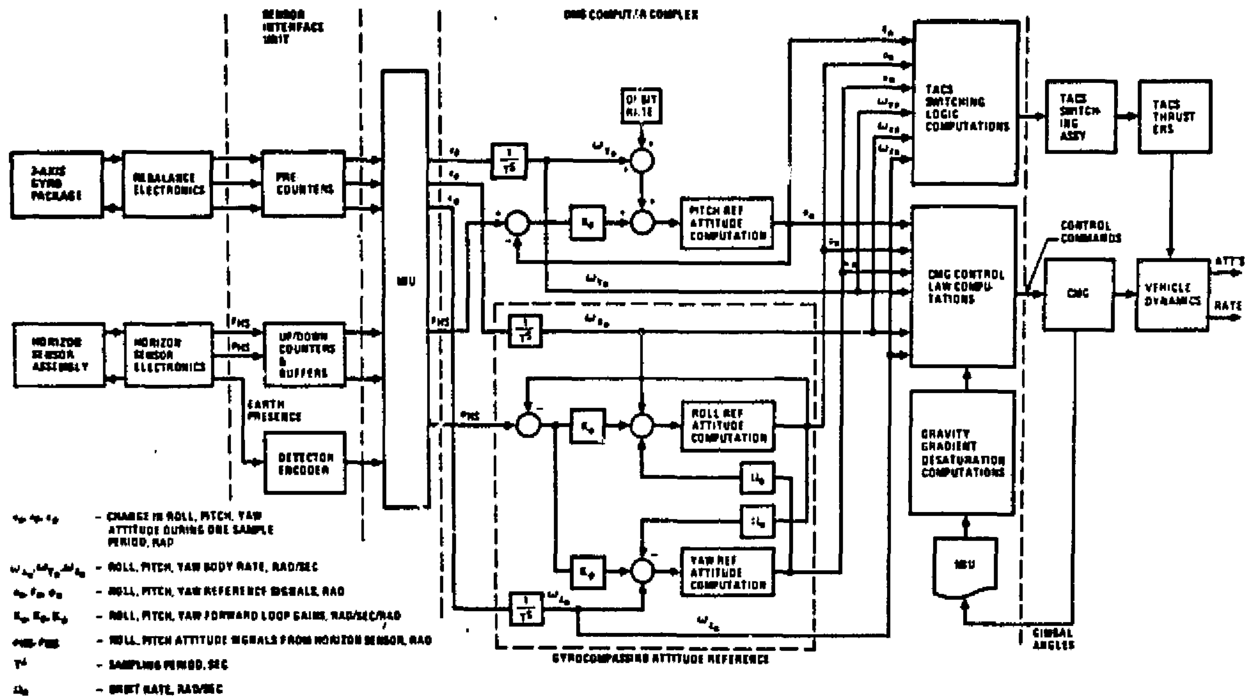

Figure 5-47. Local Vertical Attitude and Pointing Control System Configuration

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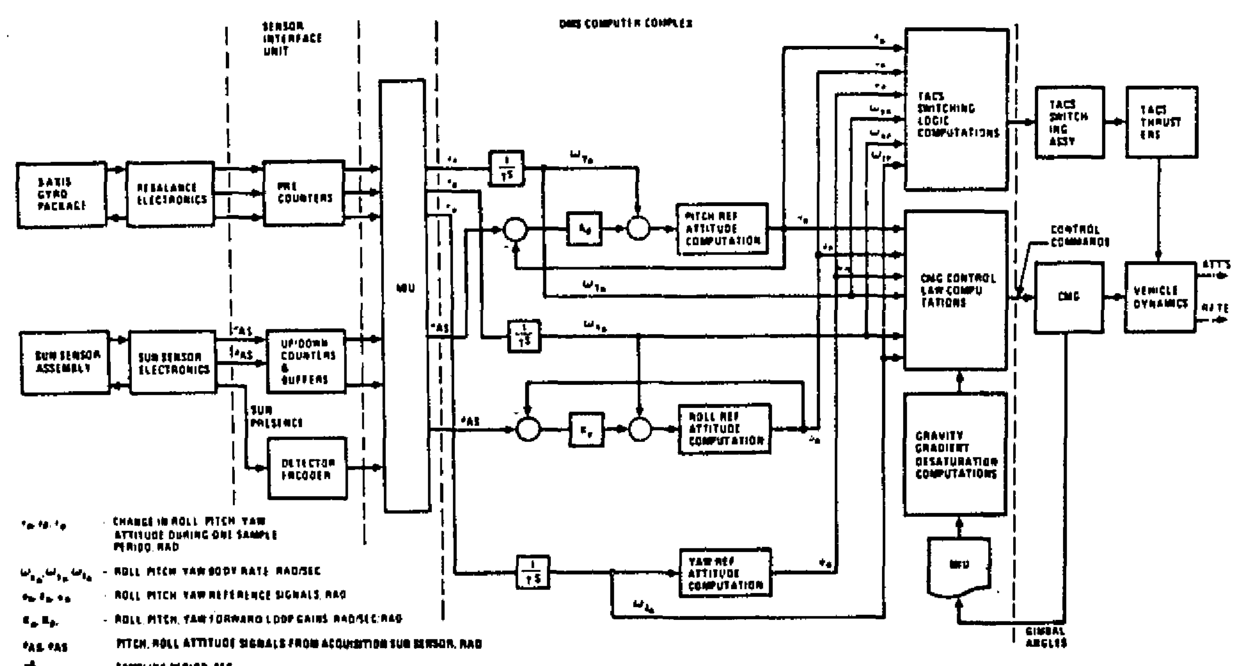

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Figure 5-48. Solar Inertial Attitude and Pointing Control System Configuration

The stellar orientation requires incorporation of gimbaled star trackers to meet attitude reference accuracy requirements. Two gimbaled trackers are required to provide three-axis inertial data. Alignment and drift compensation of the strapdown gyro package is also performed using the star trackers as the basic reference. The strapdown gyro package provides both rate and attitude information. The inertial attitude data derived from the gyros is used for short periods between star tracker updates. During operational periods when stellar orientation is not desired, the star trackers can be turned off, thus saving power and enhancing system reliability. The attitude reference configuration for the stellar orientation is shown in Figure 5-49.

Stabilization and Control System Hardware

The minimum stabilization and control system hardware needed for normal operation in the three primary orientations are listed in Table 5-27. A minimum of two 6000H CMG's are needed for three-axis control during normal operation. One gas-bearing rate gyro, orthogonally mounted to the master reference base is required for each of the three control axes. Two acquisition sun sensors provide the required pitch and roll attitude reference data while operating in the solar inertial orientation. Three-axis stellar attitude reference data are provided by the two gimbaled star trackers. Pitch and roll reference data during Z-LV operations are obtained from the four heads of the horizon edge tracker assembly. Finally, one lateral accelerometer package is needed for ΔV measurement during orbit-keeping burns. As noted in the table, all sensors must be aligned to the attitude reference base. Alignment is especially critical when considering the accuracy required of some of the stellar/solar experiments.

Although not a topic for prolonged discussion at this time, it is apparent that experiments of the stellar/solar type would require some type of continuous alignment technique to account for such error sources as (1) initial misalignment of the experiment package with respect to MOSC due to docking, (2) mechanical hysteresis of the MOSC due to maneuvers, (3) structural bending due to nonuniform thermal environment, and (4) structural vibrations due to equipment and crew motion. Further attention to appropriate means for minimizing these error sources will be provided in future tasks.

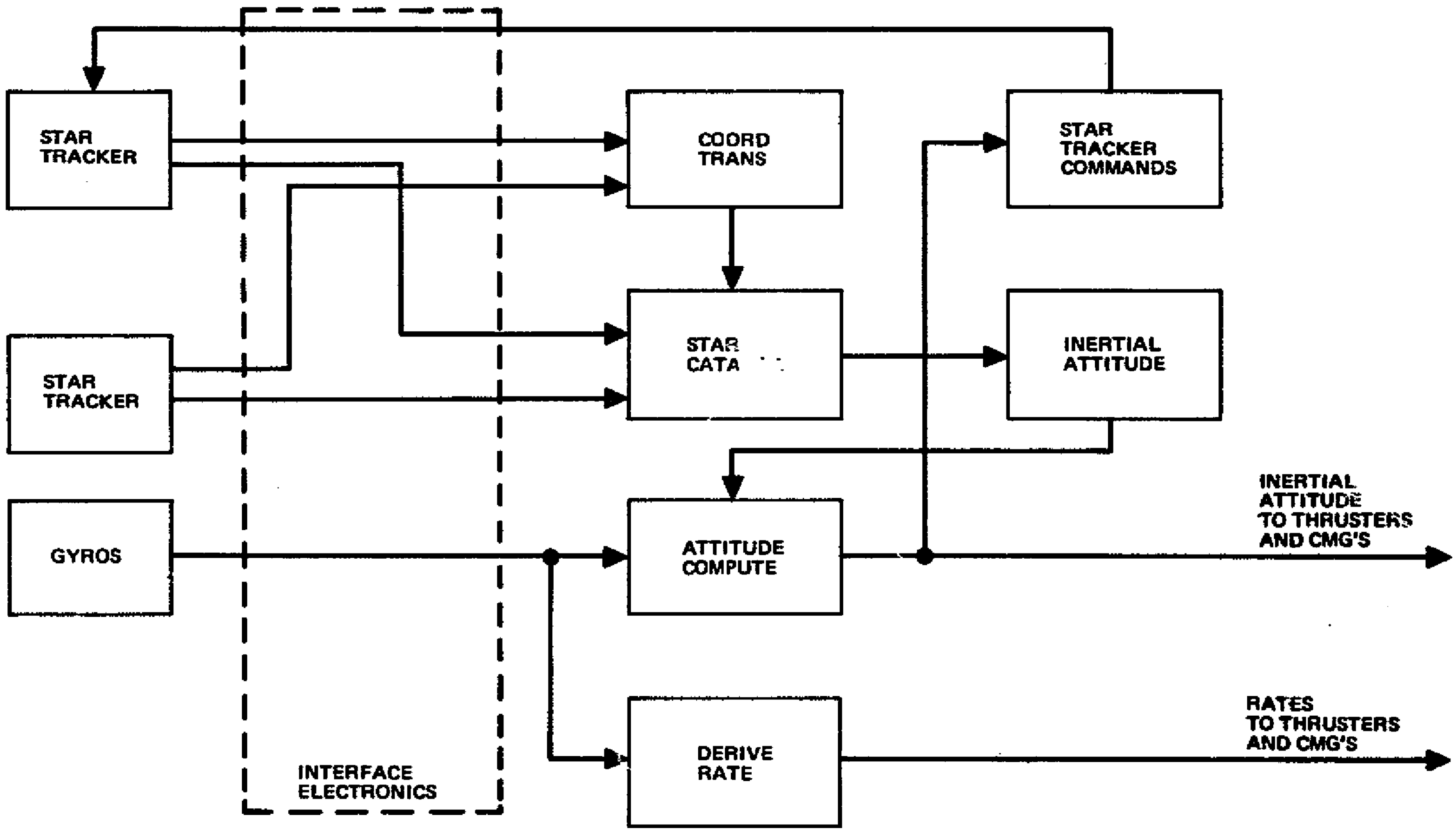

Figure 5-49. Stellar Orientation Attitude Reference

Table 5-27

STABILIZATION AND CONTROL SUBSYSTEM HARDWARE SUMMARY

Hardware Item	Total* No.	Preferred Location	Wt Est Each (lb)	Power Est Each (w)	Equipt Envelope Each (in.)	Remarks
CMG's (6000H)	2	None—Configuration currently shown on MOSC volume allocation is fine	650	60	49 sphere	Advanced version of ATM CMG. Features 9000 ft-lb-sec ang. momentum, long life, and repairability. Requires additional gyro wheel development for high rpm. Wheel failed at 112,000 rpm during initial development.
Rate Gyro (3 axes)	3	Mt'd on att. ref. base close to experiment module	1	3.	2.0 dia 3.5 length	Pulse rebalance type of gas-bearing rate. Gyro available since 1970.
Acquisition Sun Sensor (2 axes) (Solar Orientation)	2	Mt'd. near att. ref. base for alignment purposes. Free from obstruction of FOV	5	1.2	6.9x6.5x3	Same as Skylab
Star Tracker (Stellar Orientation)	2	Mtd near att. ref. base	60	39	17x12.5x21.5	Assume Skylab type
Lateral Accelerometer Assembly (3 axes)	1	Mtd on att. ref. base	-	-	-	Required for ΔV computation during orbit keeping
Horizon Edge (4 heads)(Earth Orientation)	1	Mtd. near att. ref. base 0.90° to each other - 45° off axis	45	38	6x4x10.1	Qualification tests post-1970

*Total reflects system design and does not include units needed from reliability and lifetime considerations.

Consideration has been given to estimating additional hardware (beyond that needed for normal operation) requirements for the purpose of enhancing system reliability. Table 5-28 provides the hardware estimate for the baseline 4-man MOSC as well as the 3- and 6-man configurations. Individual subassembly reliability is established in the range of 0.98 to 0.99, and it is assumed that orbital maintenance will allow exchange of hardware once useful life is expended. The table categorizes the quantity of hardware items required as to (1) those units fully powered up and operating, (2) those units operating in (1) that are active redundant, i.e., not required as part of the minimum control system hardware, and (3) the number of units in a standby redundant mode, i.e., units not participating in a fully active state in the system operation.

Table 5-28
STABILITY AND CONTROL SYSTEM HARDWARE REQUIREMENTS

	Normally Operating	Active Redundant	Standby Redundant	Total
CMG's	2	0	1	3
Rate Gyro*	2	1	1	3
Acquisition Sun Sensor	4	2	0	4
Star Trackers	2	0	2	4
Horizon Edge Tracker	1	0	1	2
Accelerometers	1	0	1	2

*Three axes

The 6000H CMG system is used to maintain stabilization and control of the vehicle during normal operation. (An auxiliary propulsion system is provided for control during docking and as the backup to the CMG's.) Normal operation requires two CMG's. One spare CMG is provided to meet the reliability goal for the long-duration MOSC missions.

Rate gyros provide the angular rate sensing necessary for stabilization and control of the vehicle. Three gas-bearing gyros in each axis are provided for the MOSC, using the pair-and-spare technique of Skylab, which allows for automatic fault isolation and correction (computer aided).

The acquisition sun sensors are required to maintain the vehicle orientation with respect to the sun. Two pairs are used for the two-axis solar inertial attitude reference information. A pair is used for each axis for comparison purposes, but only one is required for control. Hence one sensor in each axis is active redundant.

The gimbaled star trackers provide the stellar orientation attitude reference information. Two trackers are required for three-axis attitude, and the MOSC is provided with redundant trackers in the standby category.

Horizon edge trackers are required to maintain Z-LV orientation. Two tracker assemblies are required for MOSC. Each tracker has four heads; however, only three are needed for normal operation.

Accelerometer assemblies which provide ΔV information are incorporated for the MOSC orbit-keeping burns.

5.2.8 Attitude Control and Orbit-Keeping Propulsion Subsystem

The propulsion subsystem is basically required to provide attitude control during Orbiter docking operations and Orbital drag makeup throughout the mission. CMG's control attitude during other mission phases.

In the following sections the MOSC baseline propulsion subsystem is described, and the rationale and analysis associated with the sizing and component selection are discussed.

Additionally, subsystem growth capability is discussed both in terms of satisfying expanded MOSC requirements (i. e., crew size, mission duration, number of modules, etc.) and propulsion system performance improvements and added capabilities (i. e., orbital maneuvering).

5.2.8.1 Total Impulse Requirements

The total impulse requirements were determined for the baseline 90-day four-man MOSC. The total impulse budget for the MOSC propulsion subsystem is composed of two requirements, orbital drag makeup and docking

disturbances. The drag forces on the MOSC will depend on its effective area normal to the velocity vector, on drag coefficient (CDA) and on orbital altitude, which determines both atmospheric density and orbital velocity.

In orbital flight above about 80 nmi, a body is in the region of free molecular flow, and the drag coefficient can be assumed to have a value of 2.0, based on the projected area normal to velocity. The maximum and minimum control areas, shown in Figure 5-50, range from 209 ft^2 (19.4m^2) to 3,867 ft^2 (359 m^2).

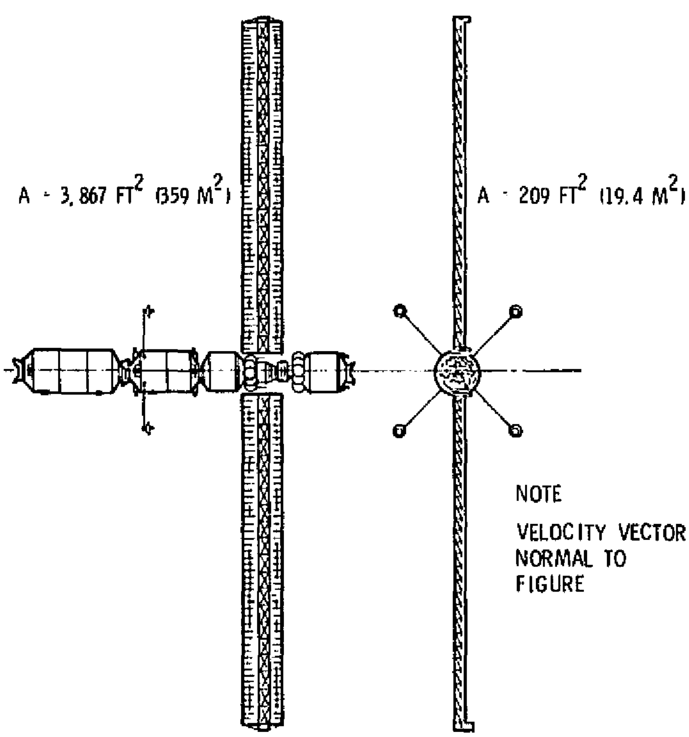

Figure 5-50. Baseline 4-Man MOSC Max and Min Frontal Area

The density of the upper atmosphere varies with the solar cycle and with the sun's longitude (local time). Tables on predicted nominal atmospheric density for the decade of MOSC operations (1980's) were obtained from MSFC Modified Jacchia Atmosphere, January 1983 Nominal Density. The year 1983 represents the mean value for the density variations over the decade. Density was presented for the mean orbital value, which corresponds to 9 a.m. local time. The density values vary from 4×10^{-13} g/cc at 100 nmi (185 km) to 4.3×10^{-17} g/cc at 300 nmi (556 km). Based on these values

and the orbital velocity at these altitudes, the drag force was calculated for the maximum and minimum values of C_DA for the MOSC between 100- and 300-nmi (185 and 556 km) circular orbital altitudes. The drag force, F_D, at any altitude scales directly with C_DA. The effect of this drag force is to cumulatively decrease the total energy in orbit. The total loss of energy in a given time period is $\int_o^t F_D dt$, or approximately $F_D t$. This represents the total impulse required to make up the drag. Figure 5-51 shows the daily drag makeup impulse for altitudes from 100 to 300 nmi (185 to 556 km) for the range of MOSC C_DA's. For the average C_DA curve, it was assumed that the MOSC flies one half the time at maximum C_DA and the remainder at minimum C_DA. This is probably a conservative assumption. Therefore, the required total impulse for the MOSC is 560 lb-sec (2,490 N-s) per day, or 50,400 lb-sec (224,179 N-s) total for a 90-day mission.

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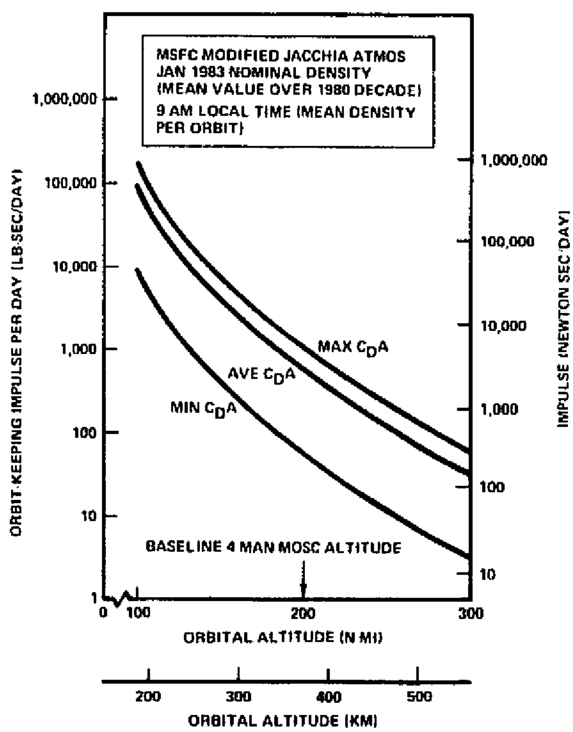


Figure 5-51. Baseline MOSC Orbit-Keeping Impulse

The determination of the impulse required to null the docking disturbances was based on the following assumptions:

A. There would be one unsuccessful docking for each successful docking.

B. The shuttle RCS would damp out the disturbances associated with a successful dock.

C. At the time of contact for an unsuccessful docking, the following conditions applied:

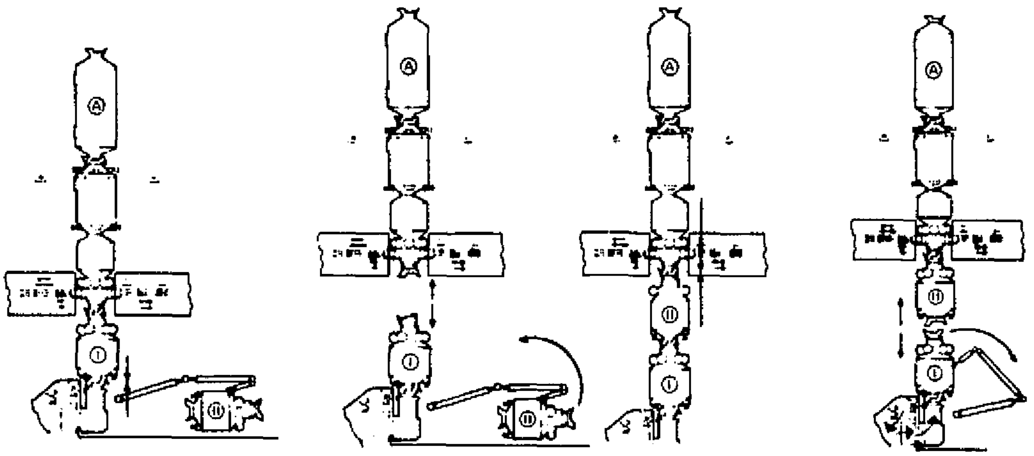
- .5 fps (.152 mps) axial velocity.
- .25-fps (.076 mps) lateral velocity.
- .5 ft (.152 m) off-centerline.
- 5° misalignment.
- 0.1° /sec angular velocity.
- 10-sec contact time.

These values are approximately 50% less than those allocated for Skylab because of the lower international docking assembly requirements and the Oriber maneuvering capability which is compatible with the docking requirements.

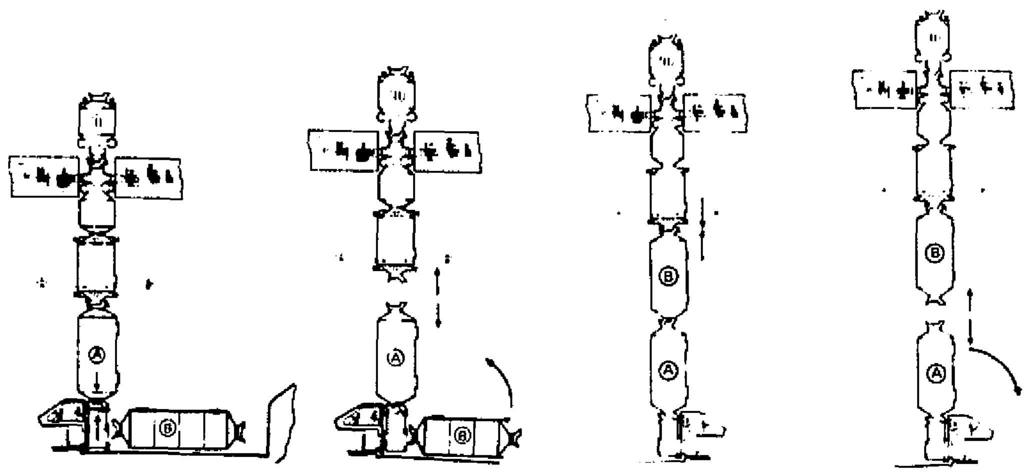
The worst-case impulse is determined by the full resupply operation shown in Figure 5-52.

Table 5-29 summarizes the impulse requirements associated with damping out an unsuccessful docking of the configurations shown in the previous figures. In every docking operation case except Number 3, the configuration includes a logistics module and, therefore, the propellant for the subsequent maneuver can be contained in the logistics module subsystem. Although the propellant for the maneuver in operation Number 3 must be aboard the service module at the time of the maneuver, it is included in the total to be stored on board the logistics module and then transferred to the service module. This sizes the tanks on the service module and establishes an operational requirement to transfer propellant from the logistics module to the service module. The service module must also have propellant on board for the Orbiter's initial docking maneuver. However, the impulse associated with this initial docking is less than that for the tank sizing case operation Number 3 (1,446 lb-sec versus 3,186 lb-sec) and, therefore, operational configuration Number 3 remains the sizing case. There is no orbit-keeping requirement during the initial buildup, because it was assumed that the subsystem-habitability module would be placed in an orbit above 200 nmi (371 km) which is allowed to decay while the module is waiting for the first Shuttle logistics flight.

The total impulse requirement for the baseline MOSC is therefore the sum of the orbit-keeping and docking-disturbance impulse (50,400 lb-sec + 10,086 lb-sec = 60,486 lb-sec).



① ORBITER DOCKS TO END OF MOSC
② SEPARATE ORBITER AT AT SM/LM I INTERFACE
③ ORBITER-LM I-LM II DOCK TO SM
④ SEPARATE ORBITER AT LM I/LM II INTERFACE



⑤ ORBITER DOCKS TO PMA END OF MOSC
⑥ SEPARATE ORBITER AT HM/PMA INTERFACE
⑦ ORBITER PMA PMB DOCK TO HM
⑧ SEPARATE ORBITER AT PMA PMB INTERFACE

NOTE: MOSC ROTATED 90° TO OPERATIONAL POSITION FOR CLARITY – LARGE PM USED TO MAXIMIZE REQUIREMENTS

Figure 5-52. Resupply Sequence (LM and PM) with Maximum Dockings

Table 5-29

MOSC BASELINE DOCKING DISTURBANCE IMPULSE
WORST-CASE RESUPPLY OPERATIONS

Docking Operation		MOSC Configuration LM	SM	HM	PM	Missed Docking Disturbance Impulse lb-sec (N-s)
Initial Dock	Orbiter LMI docks to SM		X	X		1446(6432)
1	Orbiter docks to LMI end of MOSC	X	X	X	X	3539(15741)
2	Separate Orbiter at SM/LMI interface		X	X	X	NA
3	Orbiter, LMI-LMII dock to SM		X	X	X	3186(14171)
4	Separate Orbiter at LMI/LMII interface	X	X	X	X	NA
5	Orbiter docks to PMA end of MOSC	X	X	X	X	1842(8193)
6	Separate Orbiter at HM/PMA interface	X	X	X		NA
7	Orbiter, PMA PMB dock to HM	X	X	X		1519(6756)
8	Separate Orbiter at PMA/PMB interface	X	X	X	X	NA

5.2.8.2 Thruster Size and Installation

The size of the thrusters was based on the combination of derived requirements and the assumptions of reasonable maneuvering capability and allowable disturbance angle. The firm requirement is to maintain attitude within a 0.1 deg/sec (0.00174 rad/sec) deadband rate in all axes during Orbiter docking operations. The minimum impulse bit required to meet the 0.1 deg/sec rate requirement is shown in Table 5-30 for several MOSC configurations. The MOSC configuration with the lowest moment of inertia is the service module-habitability module assembly. The minimum impulse bit required to meet the 0.1 deg/sec rate requirement is on the order of 16.4 lb-sec (72.95 N-s).

$$Ft = \text{the docking impulse or } \frac{\omega I}{L}$$

Table 5-30

MOSC PROPULSION SUBSYSTEM MINIMUM IMPULSE BITS REQUIREMENTS

	Modules	Minimum Impulse Bit Requirements lb-sec (N-s)		
		Pitch	Yaw	Roll
1	SM HM	16.7(74.3)	16.4(72.9)	37.8(168.1)
2	LM SM HM	41.0(182.4)	40.7(181.0)	39.6(176.1)
3	SM HM PM	81.6(363.0)	81.3(361.6)	39.4(175.3)
4	LM SM HM PM	238.3(1,060.0)	237.7(1,057.2)	41.3(183.7)

The impulse shown for Operation 3 (3,186 lb-sec, 14,171 N-s) was based on having thrusters on both ends of the habitability module providing a coupled moment arm of 230 inches (5.84 m). With thrusters located only on one end of the module, the moment arm is only 42 inches (1.07 m). This would have required 5.48 times (230/42) as much impulse and therefore 5.48 times as much propellant to damp out the disturbance. Inasmuch as this operation occurs when the logistics module is not attached, the propellant supply for this maneuver must be stored on board the SM/HM. Therefore, to minimize propellant requirements it was decided to place thrusters at both ends of the habitability module. The initial assessment placed them at the outer end of the habitability module in order to locate them as far as possible from the solar array. It became apparent, however, that it was advantageous to locate them at both ends of the habitability module to accommodate the wide range of CG excursions associated with the variety of configurations.

The final analysis determined the disturbance angle associated with Orbiter docking operations. This analysis was made using the 200-lb (890-N) thrust level, with thrusters located at both ends of the habitability module. The disturbance angle is the amount the MOSC would rotate during the time it takes the attitude control system to damp out the docking disturbance. The angle is given by the following equation:

$$\theta = \frac{(\text{disturbance impulse})^2 \times \text{moment arm}}{2 \times \text{thrust} \times \text{moment of inertia}}$$

The angles for each configuration in the docking operation are summarized in Table 5-31.

Table 5-31

DOCKING DISTURBANCE EXCURSION ANGLE

Operation*	Disturbance Impulse lb-sec (N-s)	Excursion Angle ( )
Initial Docking To SM-HM	1446 (6432)	8.9
1	3539 (15741)	3.7
3	3186 (14171)	7.8
5	1842 (8193)	[illegible].0
7	1519 (6757)	[illegible].4

*As described in Figure 5-52

The maximum disturbance angle occurs at initial buildup docking and is less than 10°. During normal resupply operations this angle never exceeds 8°. This amount of potential angular drift, which might occur after a missed docking, does not appear to be excessive as long as the docking maneuver is done with the axis of the solar panels perpendicular to the Orbiter payload by centerline (i.e., Orbiter x axis), as shown in Figure 5-53. This is the required configuration to prevent the solar panels from colliding with the Orbiter's vertical empennage. The lower illustration shows the MOSC in the required docking orientation; shown in phantom is the position of the solar panel after recovery from a missed dock (rotated 8.9°). As can be seen, there is adequate clearance between the MOSC solar array and the Orbiter.

One factor that was not assessed in the thrust level selection was the effect on the solar array design. However, loads associated with docking disturbances are probably more severe than the thrust loads.

5.2.8.3 Propellant Selection

The criteria assessed in selecting a propellant combination for the MOSC propulsion subsystem included weight, propellant transfer, performance, contamination characteristics, system lifetime, and Orbiter performance. The assessment was primarily qualitative, based on previous studies and

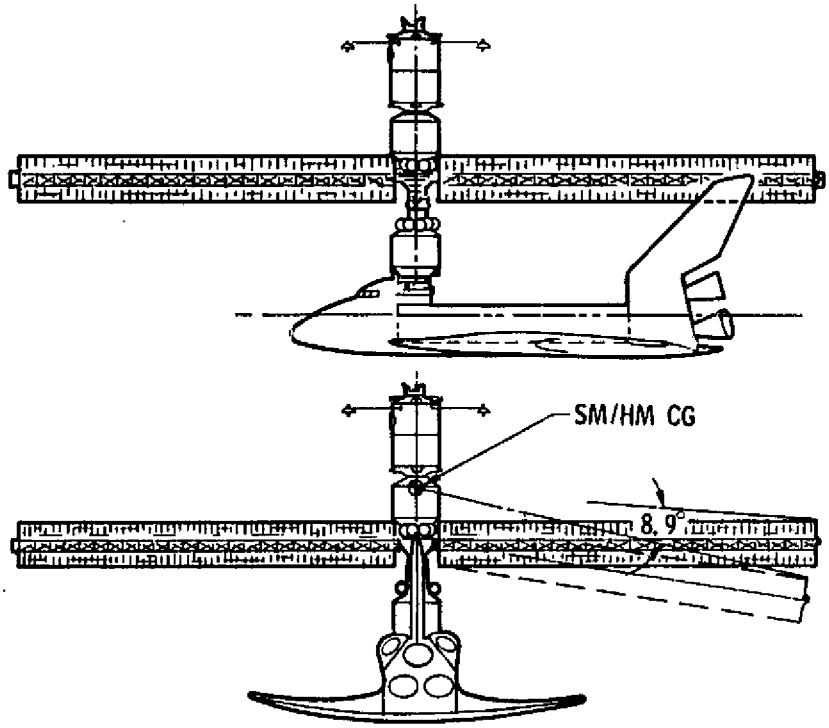


Figure 5-53. Orbiter/MOSC Docking Relationship

test information. The three options are cold gas N_2, monopropellant, and bipropellant hypergolics. A comparative matrix of these options is shown in Table 5-32. The cold gas system was selected primarily on the basis of negligible contamination potential, relative ease of propellant transfer, and the fact that the mission Shuttle performance margins allowed the use of the heavier system. Both the other options have a much higher contamination potential, and in view of the attitude control thrusters location in close proximity to the payload module, the negligible contamination with N_2 weighed heavily in the selection. Both the other options would have required some sort of reusable propellant zero-g orientation device such as bladders, and the development of such devices would certainly add additional cost to the system. The available weight and volume capacity of the MOSC logistics concept (a resupply logistics module) was more than adequate to handle the 1,000 pounds (454 kg) of gaseous N_2 propellant.

Table 5-32

MOSC PROPELLANT OPTION COMPARISON

	Criteria				
Option	Performance	Propellant Transfer Considerations	Contamination Potential	Potential Reuse Problems	System Lifetime
Gaseous Nitrogen	Adequate	Gaseous Transfer	Negligible	Considered not a problem	Not limited
Monopropellant Hydrazine	Good	Zero-g liquid transfer	Moderate	Positive expulsion devices	Catalyst bed limitations
Bipropellant N_2O_4/MMH	Best	Zero-g liquid transfer, 2 fluids	High	Positive expulsion devices	High-temperature thrusters

5.2.8.4 Baseline Subsystem Description

The location and orientation of the thrusters are shown in Figure 5-54. Pitch and yaw maneuvers are made with the eight radially oriented thrusters located four each on either end of the habitability module. Roll maneuvers are made using the four tangentially oriented thrusters located on the payload docking end of the habitability module. The two thrusters on the aft end of the logistics module are used to provide the necessary orbital drag makeup. All 14 thrusters are identical, and Table 5-33 summarizes their characteristics.

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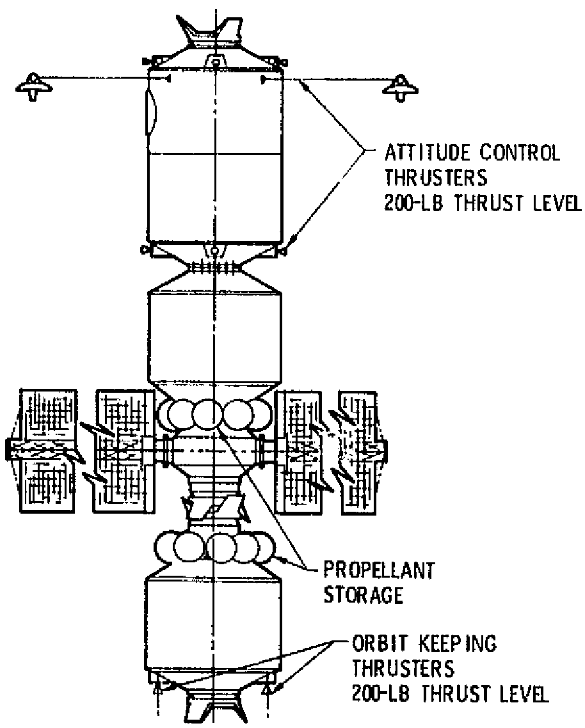


Figure 5-54. Baseline 4-Man MOSC Propulsion Subsystem External Configuration

The performance of the thruster as a function of gas storage temperature is shown in Figure 5-55.

Based on the total impulse requirements stated in Subsection 3.6.1, the total usable propellant required is 1,008 pounds (457 kg). Of this, 840 pounds (381 kg) is required for orbital drag makeup, with the remainder required for attitude control during docking. Figure 5-56 shows the effect of operational orbit altitude on mission duration with a fixed amount of orbit-keeping propellant.

Table 5-33
THRUSTER CHARACTERISTICS

Thrust	200 lb (890 N)
Operating Pressure	300 psi (2.07×10^6 N/m^2)
Expansion Ratio	50:1
Avg I_{SP}	60 sec $\left(588 \frac{N-s}{kg}\right)$
Length	9 in. (0.29 m)
Diameter	5 in. (0.13 m)
Weight (without valves)	5.5 lb (2.49 kg)

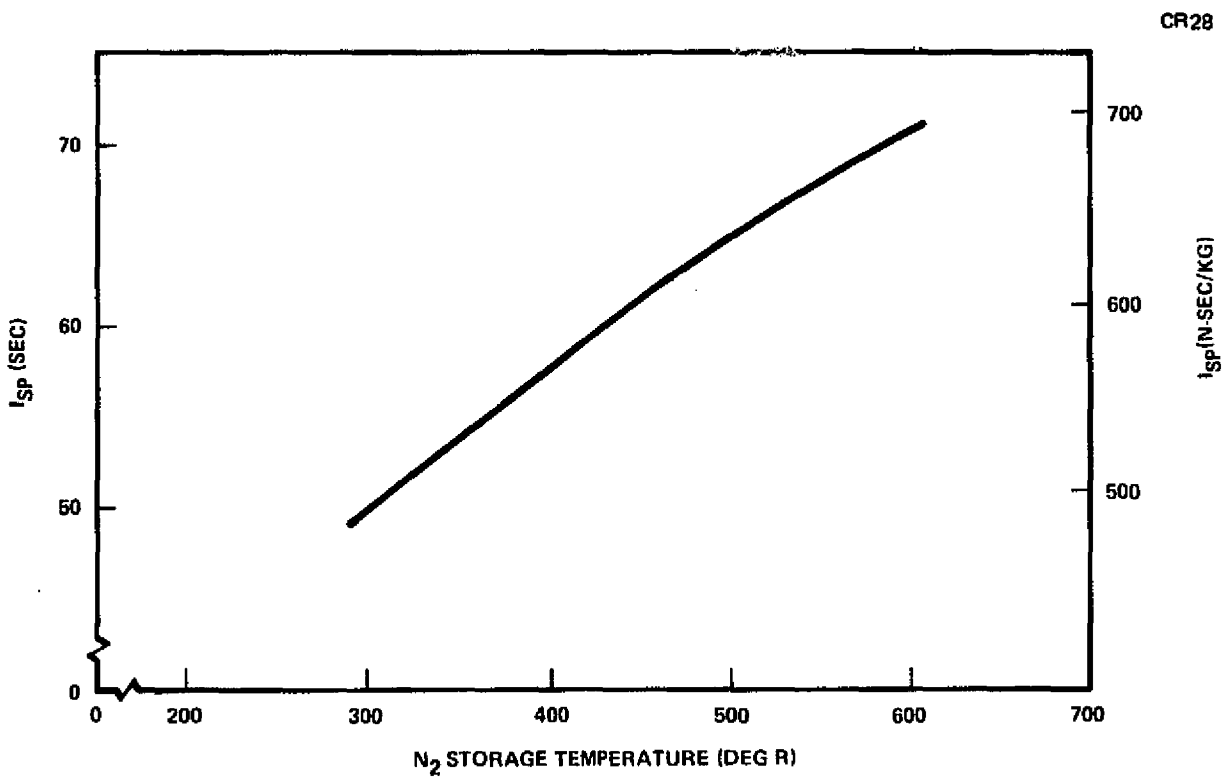


Figure 5-55. Effect of Temperature on I_{SP}

Figure 5-57 is a schematic of the MOSC propulsion subsystem. All the propellant is stored initially in fifteen 25-inch (0.635-m) -diameter spherical bottles located on the logistics module. These bottles are of composite wrap construction and are being proposed for use in the Shuttle ECLS subsystem. The weight of each bottle is 78 pounds (35 kg). These bottles are filled initially at 3,300 psi (2.275×10^7 N/m^2). Enough propellant must be stored on the HM-SM to perform the one docking operation

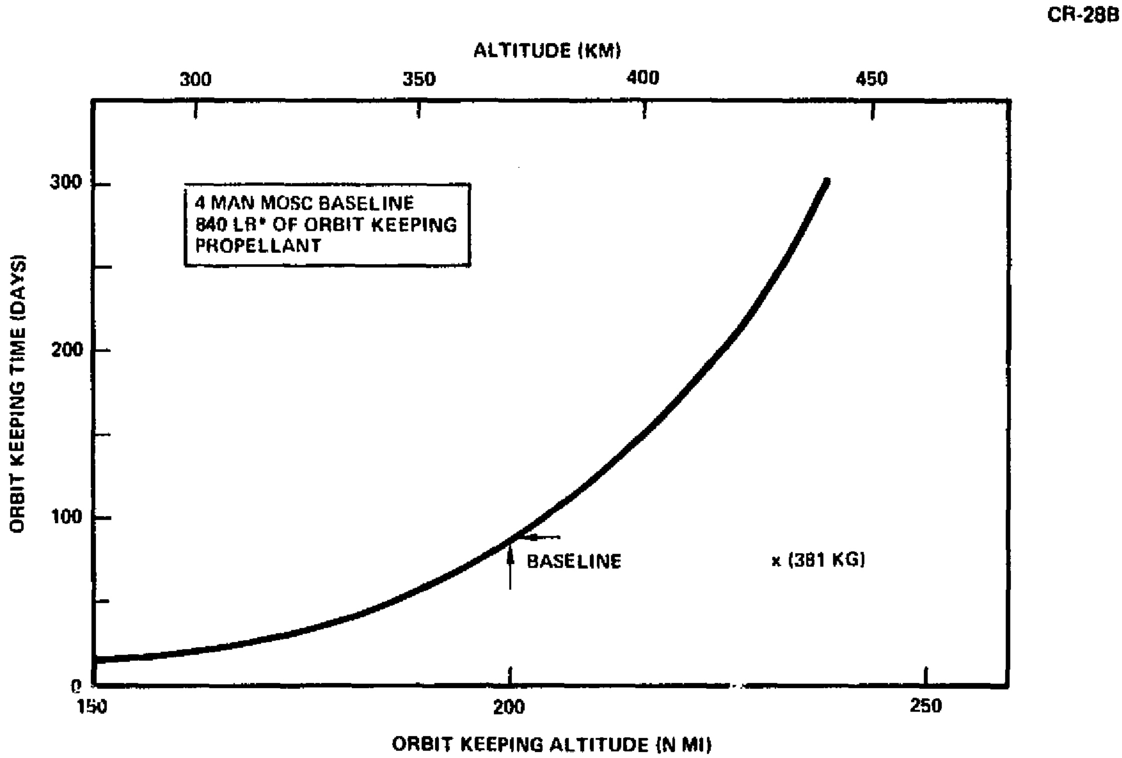


Figure 5-56. Effect of Altitude on Staytime (Constant Wp) Baseline 4-Man MOSC

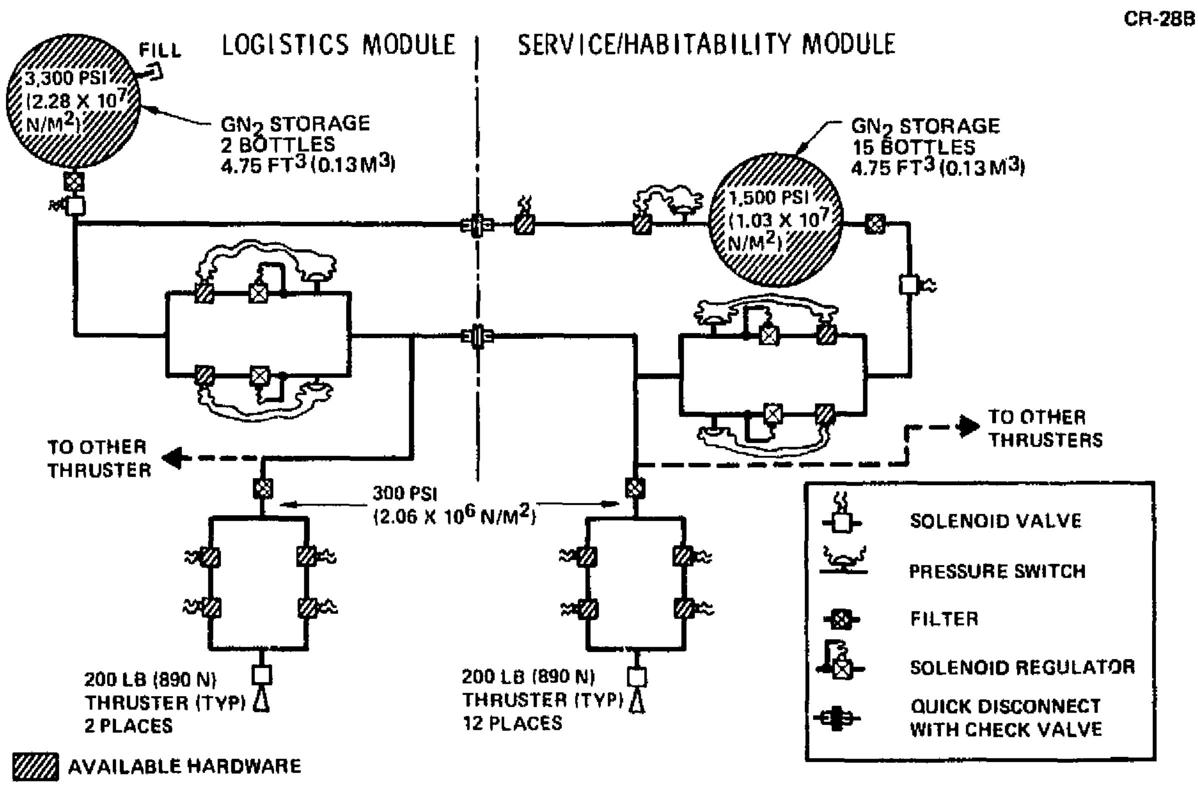


Figure 5-57. Baseline 4-Man MOSC Propulsion Subsystem Schematic

during resupply when there is no attached logistics module. This amounts to 53.1 pounds (24 kg). Two of the same bottles are required to store this propellant. During a normal resupply operation these bottles are filled from the bottles on the logistics module. They are then isolated from the system with proper valving and stored until required for use. On the initial launch of the SM-HM these bottles can be filled with approximately 135 pounds (61 kg) of usable propellant at 3,300 psi. The thrusters operate normally at a regulated 300 psi (2.1×10^6 N/m^2) with propellant from the tanks on the logistics module. Each thruster is controlled with quad redundant valves in a configuration similar to that used in Skylab.

5.2.8.5 Growth Versions

Growth was assessed from two standpoints: growth of the MOSC system in terms of additional modules and more demanding mission requirements such as extended duration and increased crew size; and growth potential of the MOSC propulsion system in terms of performance and capability.

The impact to the baseline propulsion subsystem for physical growth of the MOSC configuration is mainly in the form of increased propellant weight. Over 80 percent of the propellant for the baseline system was required for drag makeup. The amount of propellant required at constant altitude is directly proportional to the area normal to the velocity vector. The addition of more modules will increase the area and therefore the required propellant. It costs approximately 0.4 pounds of propellant per square foot of added area normal to the velocity vector (4.9 kg/m^2) for 90 days, based on an I_{SP} of 60 seconds (588 N-s/kg).

The impact of adding so-called "large space structures" could be prohibitive in terms of propellant requirements unless the operation took place at altitudes in excess of 200 nmi (371 km). The propellant-to-area ratio at 300 nmi (556 km) is on the order of 0.02 psf (0.098 kg/m^2) or 1/20th the amount at 200 nmi (371 km) for 90 days.

Should the MOSC growth substantially increase propellant requirements, it might be prudent to consider changing the system over to a different propellant type or using additional propellant to perform the orbit keeping.

This leads to an assessment of the growth capability of the propulsion system in terms of performance. Because the orbit-keeping thrusters are located on the logistics module, along with the propellant, it would be relatively uncomplicated to change some time to a bipropellant system, thus improving the performance. This change would offer a five-fold improvement in specific impulse. With the improved performance, one might consider performing other orbital maneuvers, such as altitude changes.

5.2.9 Environmental Protection

This subsystem provides vehicle protection for space environment hazards of the low Earth orbital altitudes of 100 to 300 nmi. Within the design activity, it is related to and coordinated with the structural design of the primary structure.

5.2.9.1 Radiator/Meteoroid Shroud

The Spacelab pressure shell design uses high-performance, multilayer insulation installed on the external surface. The Spacelab's attached mode of operation will not require space radiators or full external surface meteroid protection due to Orbitor subsystem support and structural protection. Therefore, to provide the free-flying MOSC with the necessary meteroid protection and heat rejection capability, the integral meteoroid shield and space radiator system shown in Figure 5-58 is recommended. It possesses the required performance characteristics with minimum weight and complexity.

The external shroud encapsulates the pressure shell and provides the space radiating surface for the ECLS subsystem, meteoroid protection, and thermal protection. The 0.016-inch (0.04-cm) outer surface is formed from extruded aluminum sections which contain the flow passages for the ECLSS radiator fluid. A second bumper, to protect the 0.5-inch (1.27 cm) blanket of high-performance insulation, is attached to the radiator extrusion forming a box section. The assembly is installed over the pressure shell and supported by fiberglass insulators. The outside diameter of the radiator is 166.84 inches (4.23 m). Both the subsystems and habitability modules have active and redundant radiator systems, either of which is capable of accommodating the nominal vehicle heat load. To maximize the radiator heat-

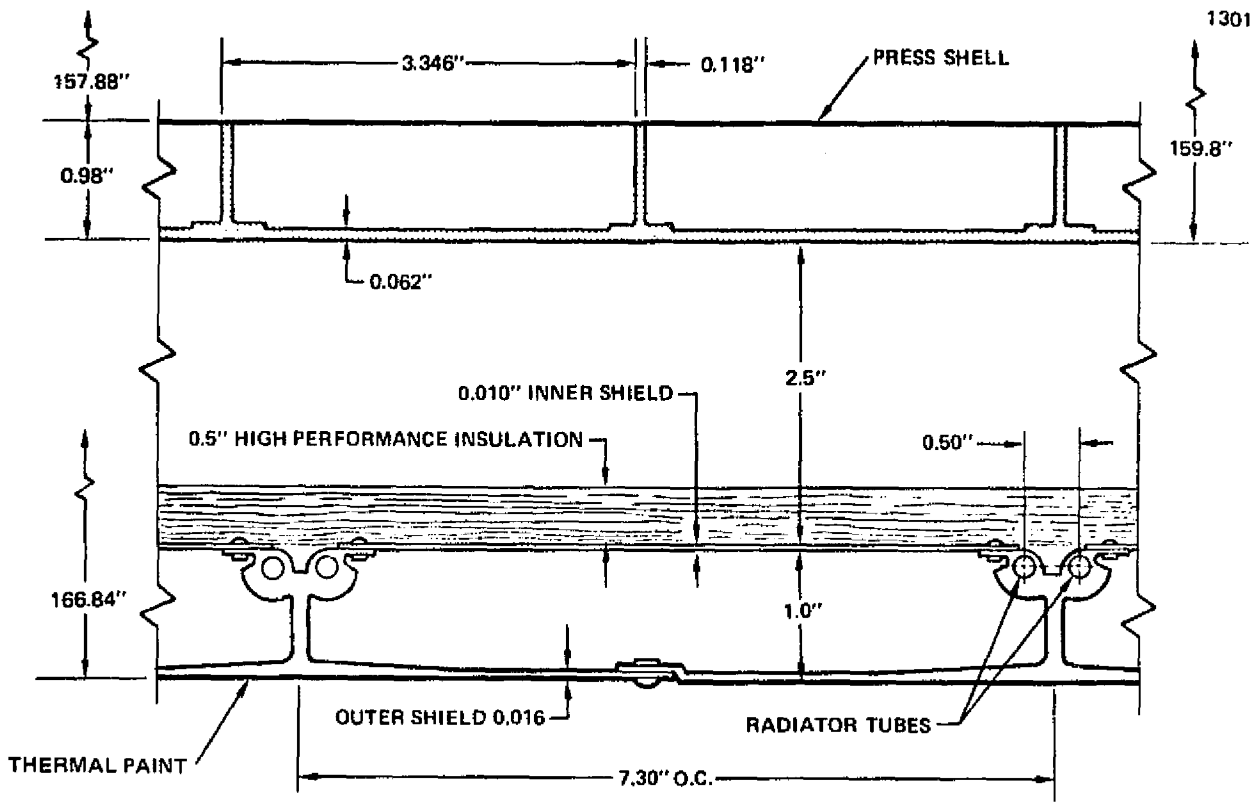
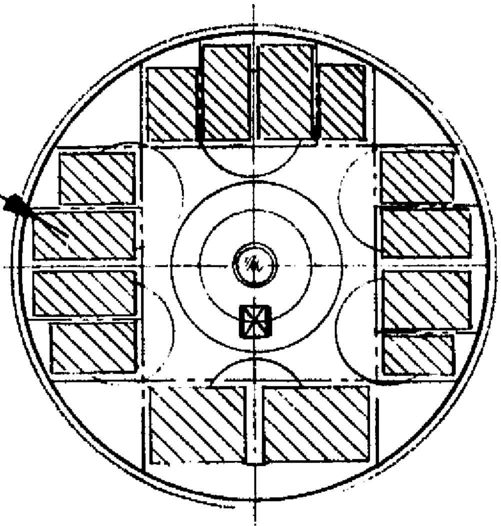
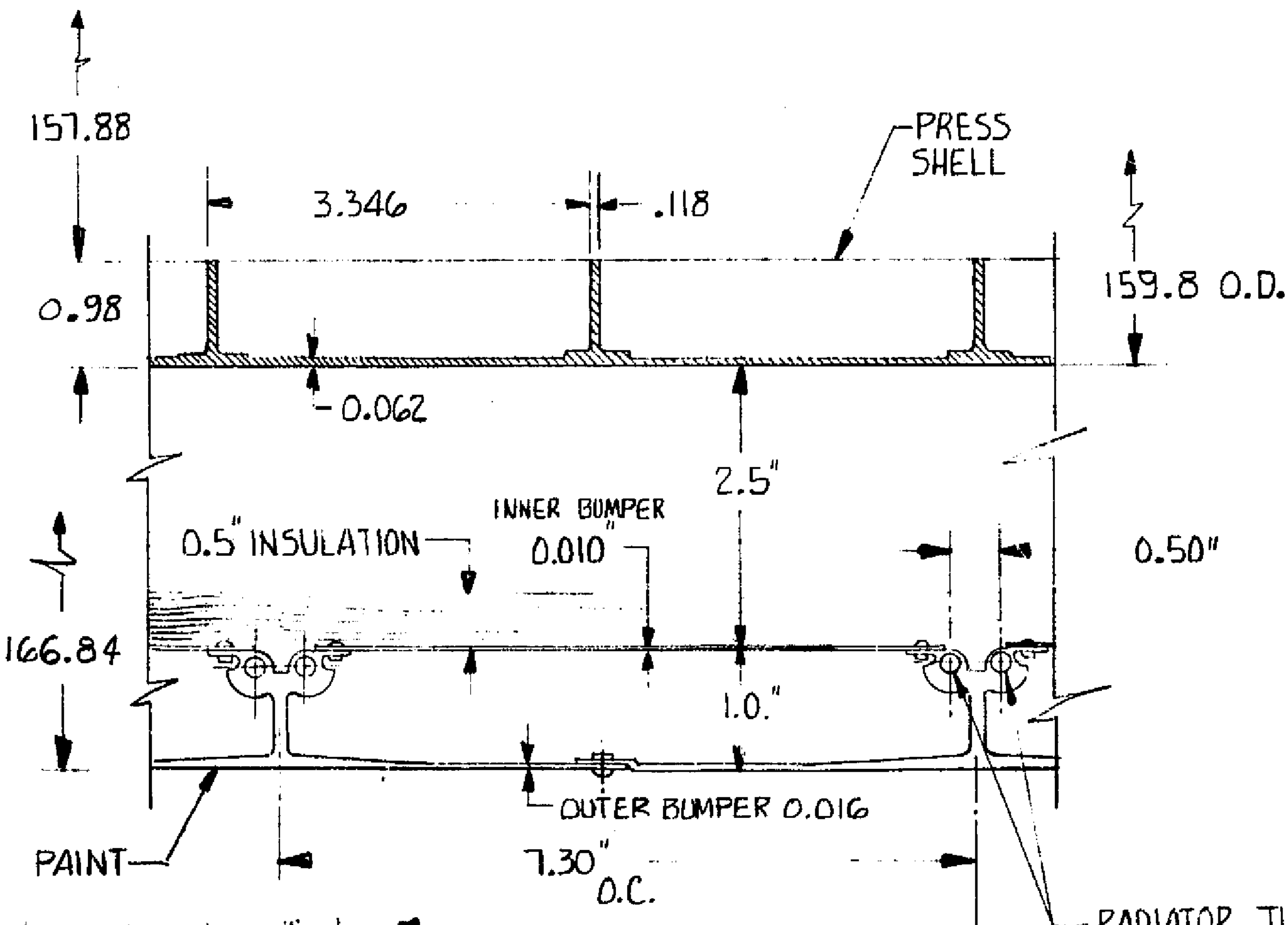


Figure 5-58. Structural Mechanical Subsystem Meteoroid Shield/Radiator

rejection capability, the inlet and return manifolds for the active and redundant radiators are to be located 90° apart so that the radiator with best orientation relative to the sun at a particular time can be selected as the active system. The extruded radiator tubes which are an integral part of the radiator/meteoroid shield are longitudinally oriented and spaced 5° apart. The end manifold is arranged so that each fluid-pass travels one-half way around the vehicle circumference so that the outlet is 180° from the inlet.



SECTION G-G



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VIEW K
(RADIATOR / METEROID SHIELD)

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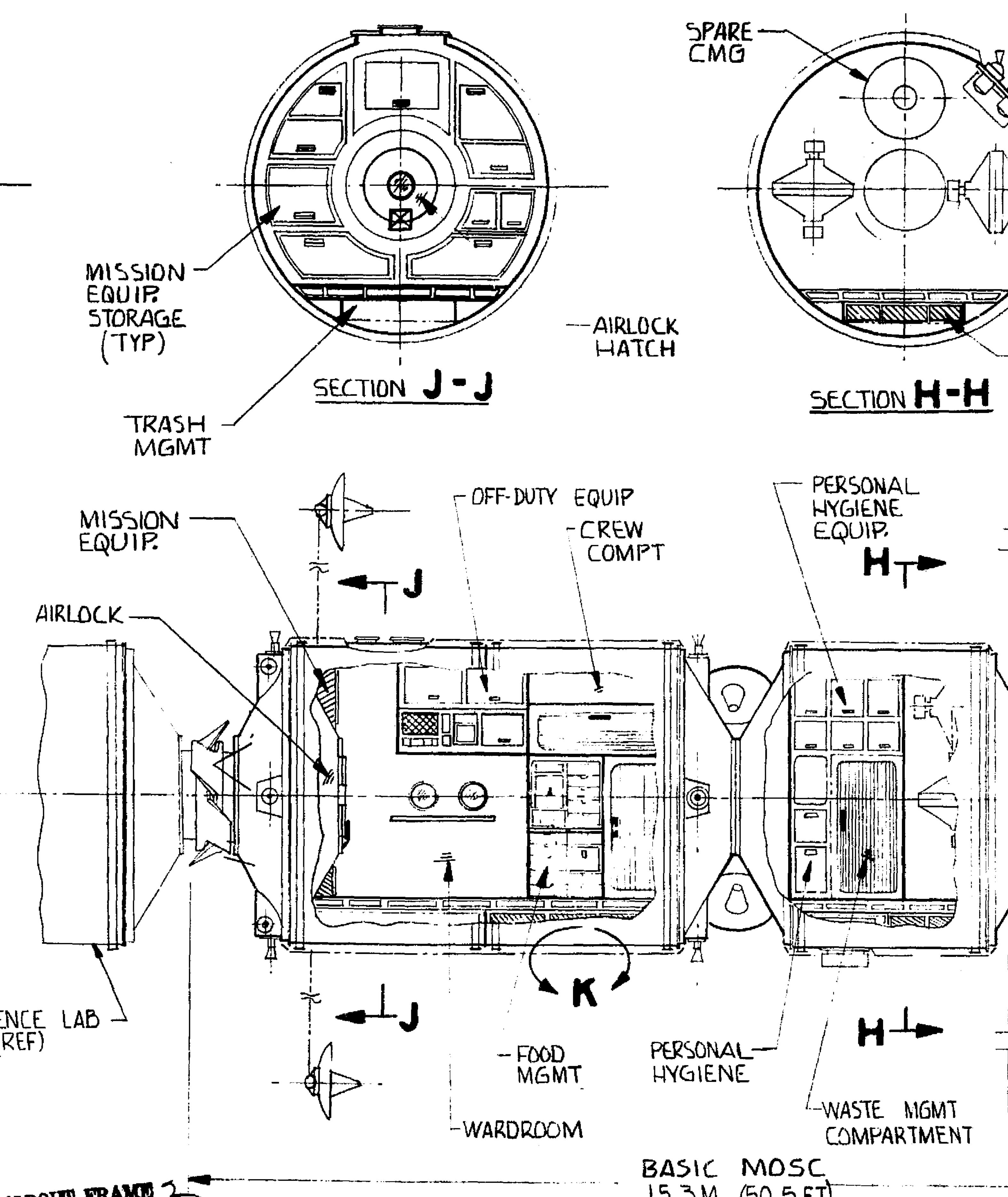

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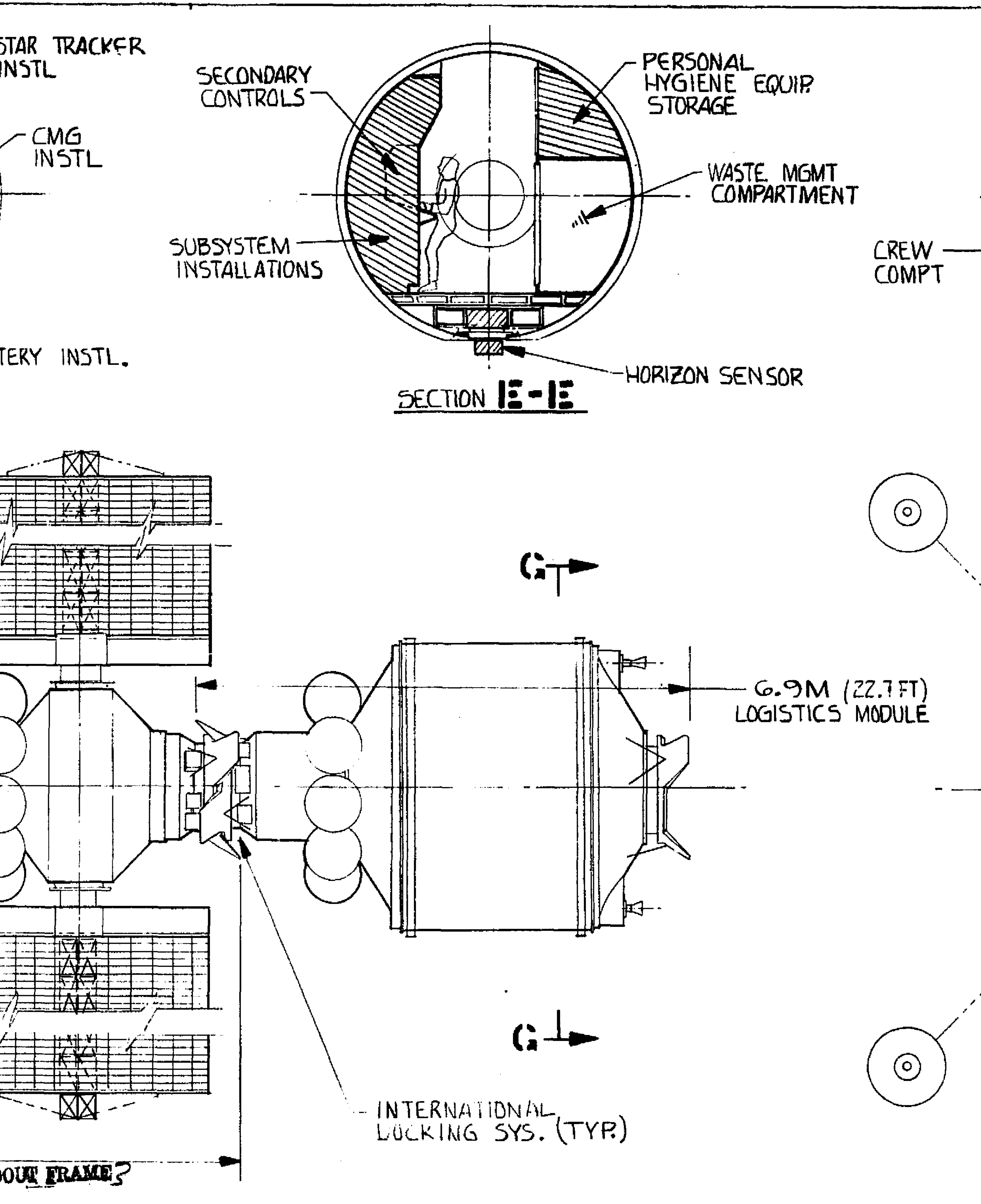
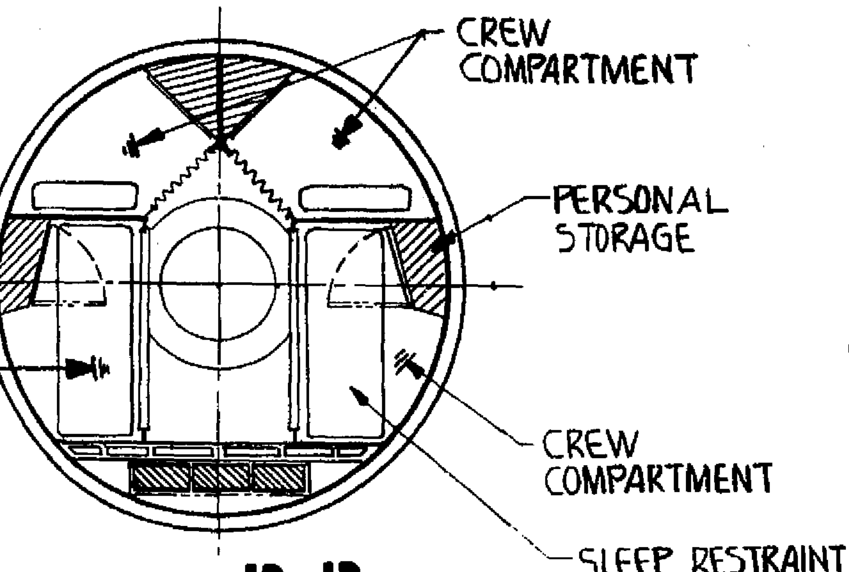

STAR TRACKER
INSTL
CMG
INSTL
TERY INSTL.
SECONDARY
CONTROLS
SUBSYSTEM
INSTALLATIONS
PERSONAL
HYGIENE EQUIP
STORAGE
WASTE MGMT
COMPARTMENT
CREW
COMPT
HORIZON SENSOR
SECTION E-E
G
G
6.9M (22.7 FT)
LOGISTICS MODULE
INTERNATIONAL
LOCKING SYS. (TYP)
OUT FRAME



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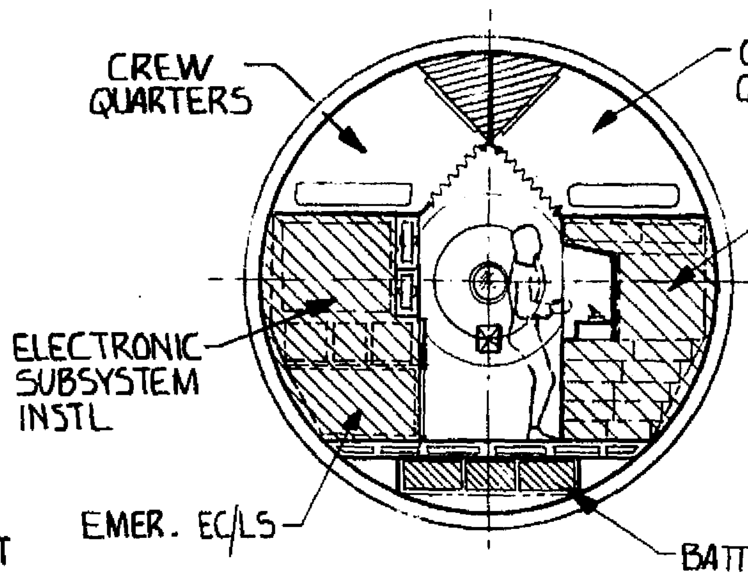
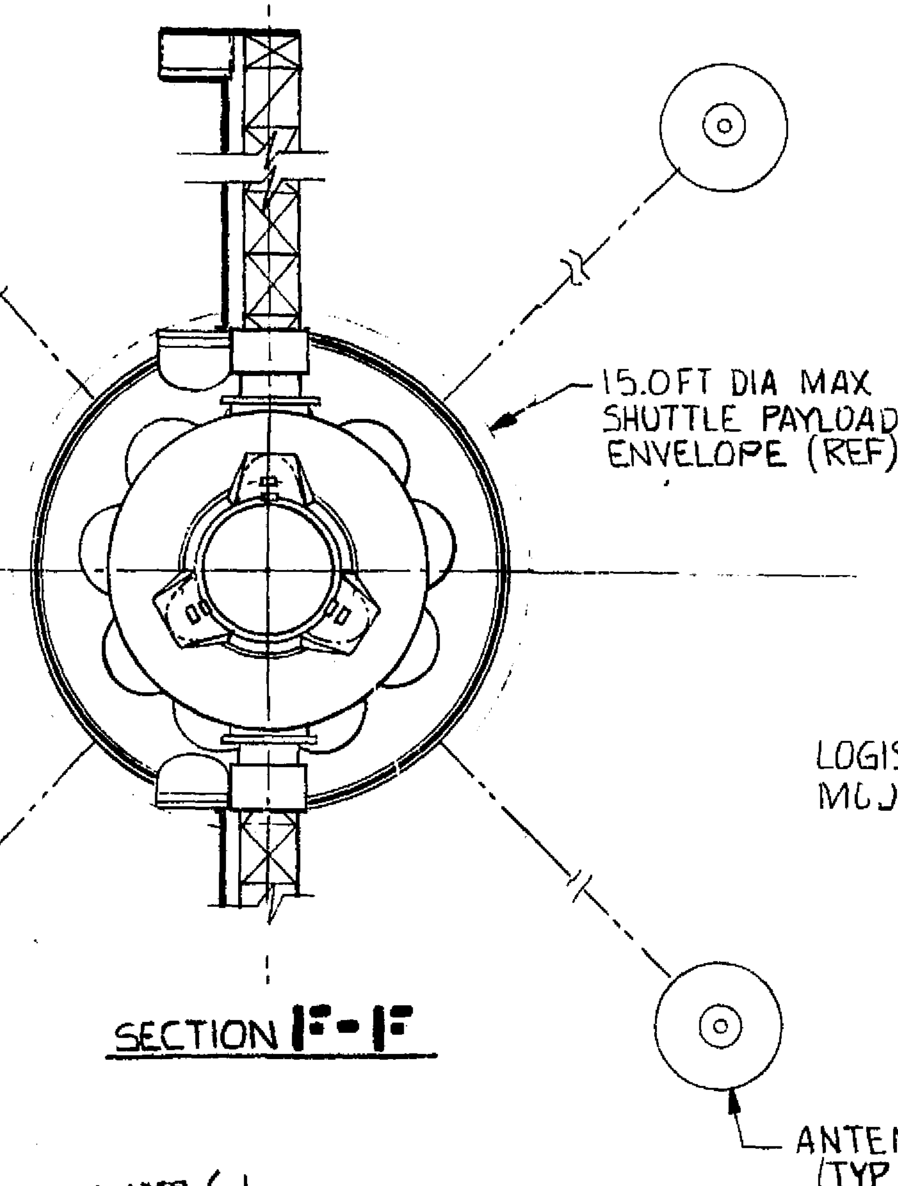
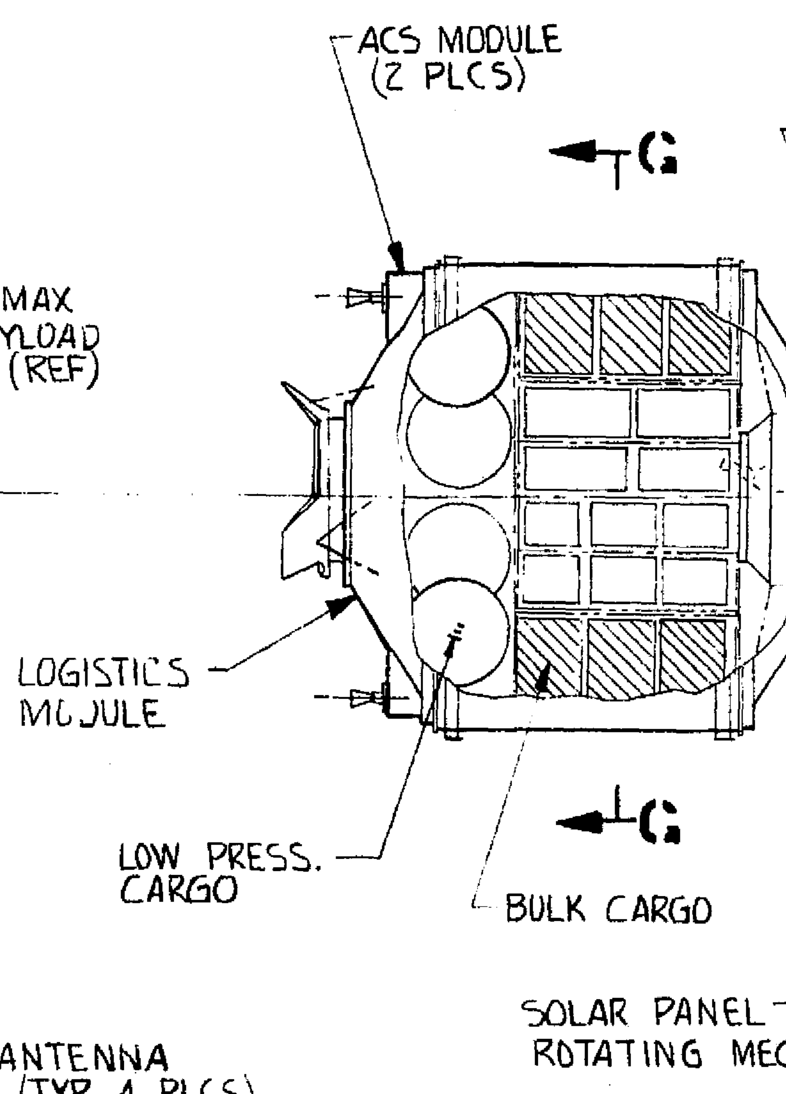


SECTION C-C



SECTION F-F



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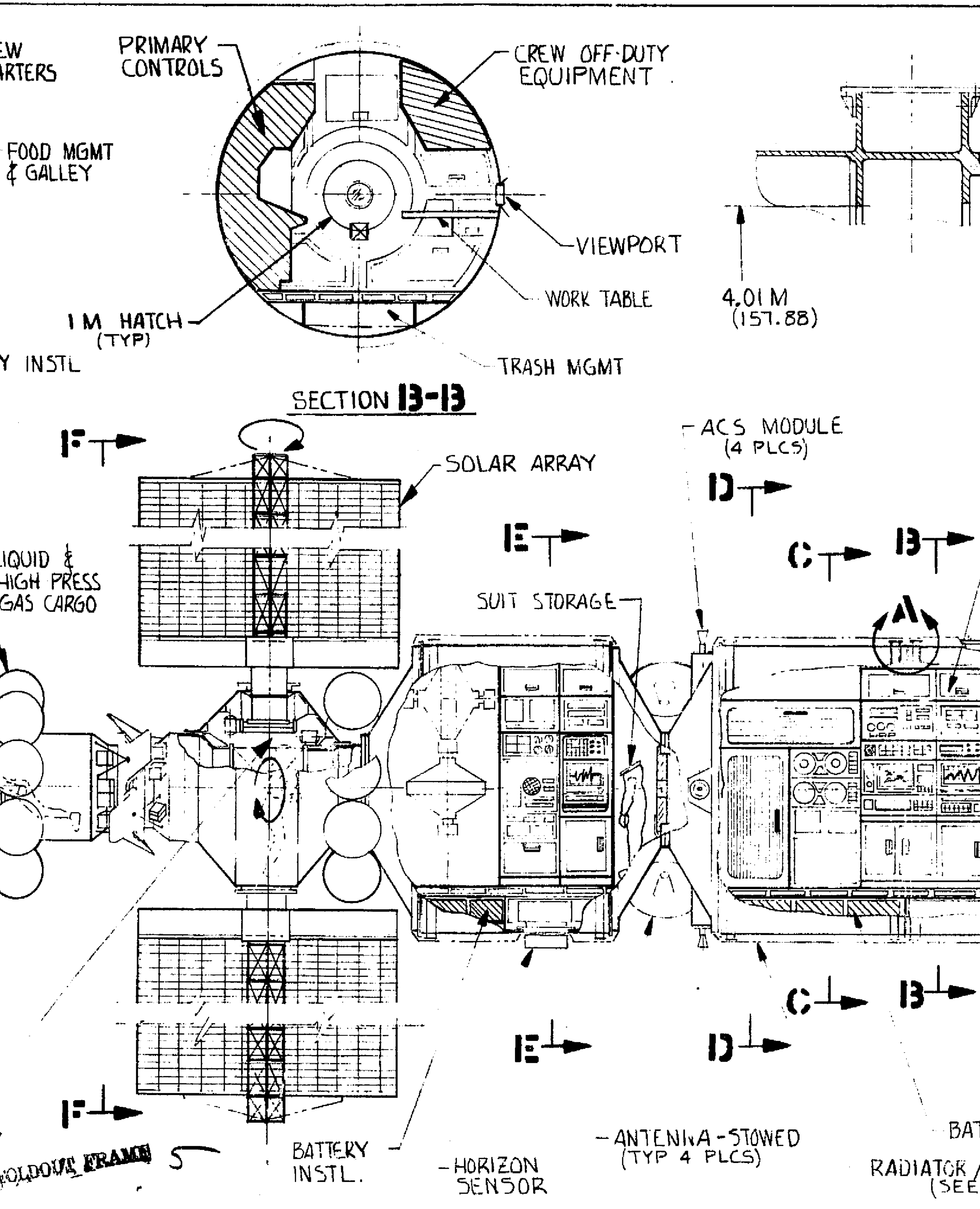

EW
ARTERS
PRIMARY
CONTROLS
CREW OFF-DUTY
EQUIPMENT
FOOD MGMT
& GALLEY
VIEWPORT
WORK TABLE
4.01 M
(157.88)
1 M HATCH
(TYP)
Y INSTL
TRASH MGMT
SECTION B-B
F
ACS MODULE
(4 PLCS)
SOLAR ARRAY
D
E
C
B
LIQUID &
HIGH PRESS
GAS CARGO
SUIT STORAGE
A
BATTERY
INSTL.
HORIZON
SENSOR
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RADIATOR
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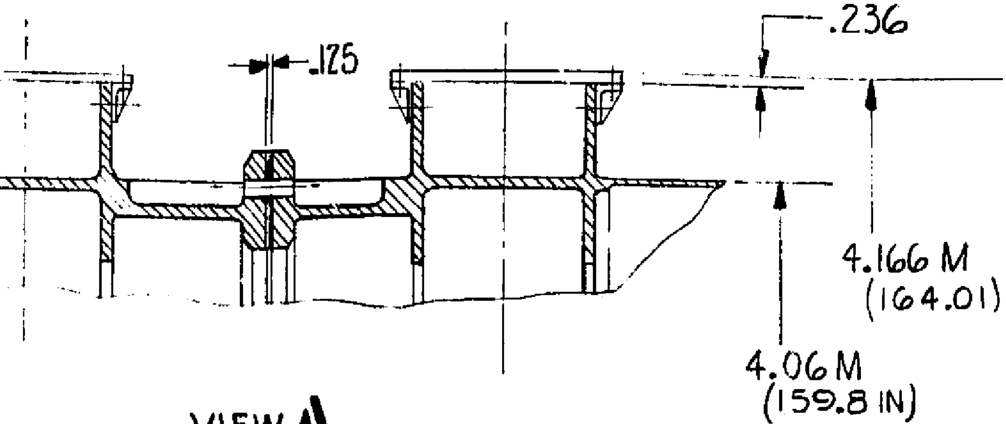
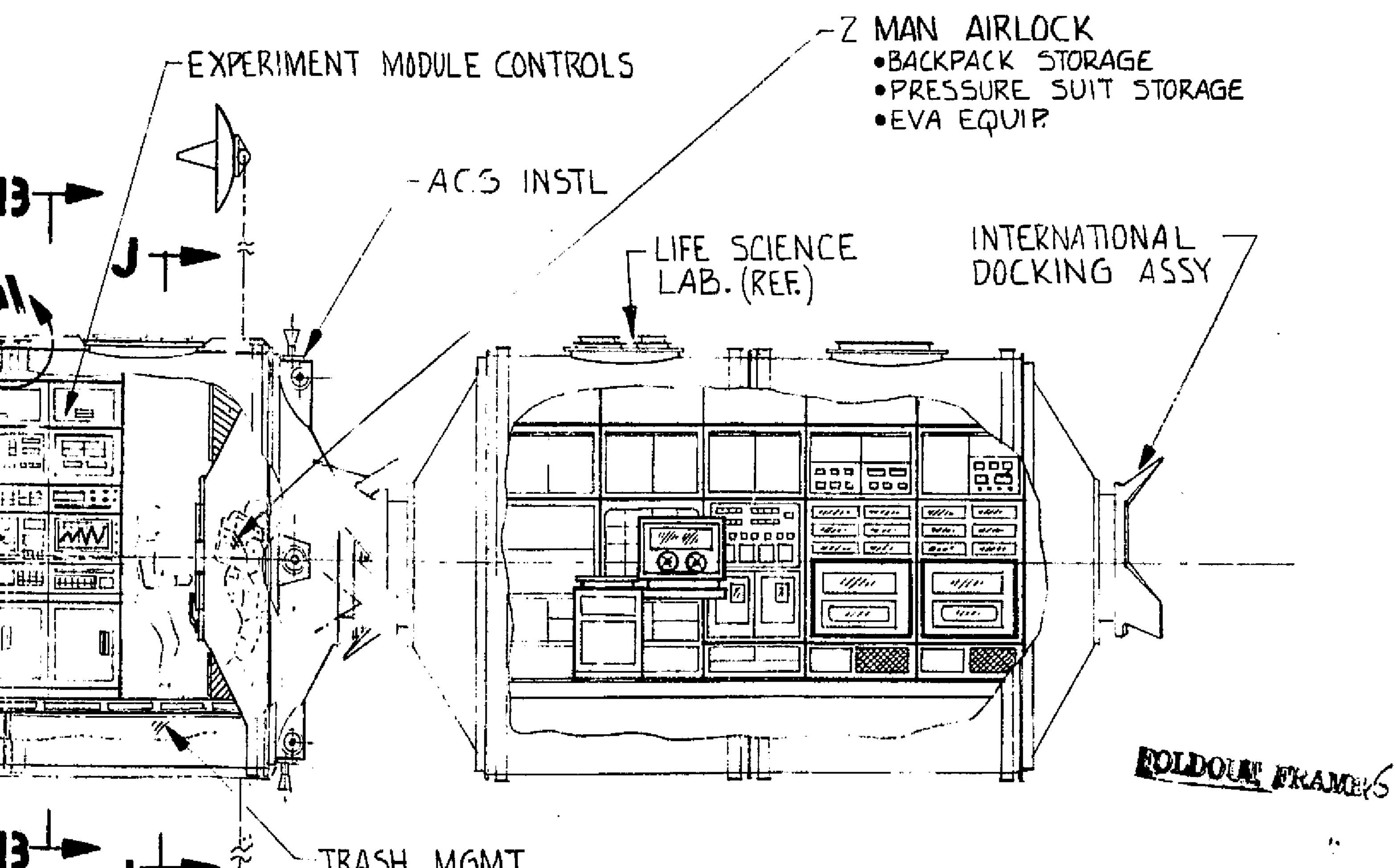
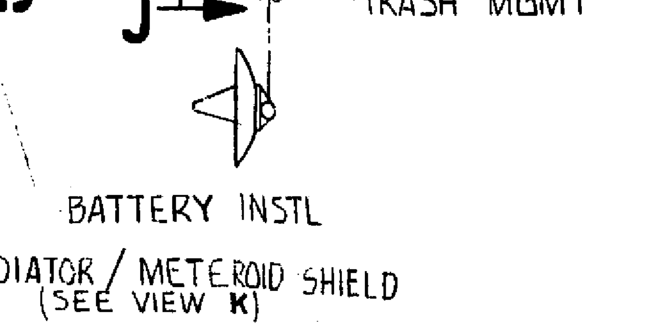


VIEW A
(PRESSURE SHELL JOINT)





CONTRACT NO.

ORIGINAL DATE OF DRAWING

PREPARED	G KING	25 MAR 75
CHECKED		May 75
ENGINEER		

DESIGN ACTIVITY APPROVAL

CUSTOMER APPROVAL

MCDONNELL DOUGLAS ASTRONAUTICS CO.
WESTERN DIVISION
HUNTINGTON BEACH, CALIFORNIA
MCDONNELL DOUGLAS

INBOARD PROFILE
BASELINE 4-MAN MOSC

SIZE	CODE IDENT NO.	DRAWING NO.
	18355	GK 032575

SCALE 1/40 | SHEET 1 OF 1

Section 6
OPERATIONS ANALYSIS

The Shuttle system is capable of supporting a traffic model and launch rate that are an order-of-magnitude greater than those of any previous manned space-flight program. The success of Space Shuttle and its payload programs will depend to a great extent on efficient ground operations. As this activity is currently being developed simultaneously for both Space Shuttle and Spacelab, it was assumed for purposes of this study that the MOSC space station would be similar to Spacelab in prelaunch and postmission support. Thus, as the Spacelab ground operations are defined in detail during the coming months, they can be immediately evaluated as a first step in the evolutionary growth to the manned space station era.

In the area of orbital operations, however, a different situation exists. The free-flying MOSC space station, unlike the Spacelab, will be involved in orbital rendezvous and docking, addition and removal of modules, and autonomous flight operations. The role of the crew will assume a new dimension in the continuing operation of a long-duration space station supporting a demanding payload program; therefore, crew safety techniques and orbital operations must be employed that are consistent with precedents and standards established on previous manned space-flight programs. To ensure the early application and consideration of operational and crew safety factors, the operations analysis was conducted in conjunction with the selection of MOSC configurations.

6.1 PRELAUNCH OPERATIONS

The ground operations phase of a manned space-flight program encompasses many distinct tasks and operations which occur during the prelaunch preparations, checkout, launch, and postlanding turnaround. Of these many tasks, only two have a direct influence on the vehicle configuration. These are the internal access requirements after installation in the Orbiter cargo

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bay and the checkout and loading interface umbilicals. The internal access requirements have been analyzed, and the umbilical locations are the subject of subsystem preliminary design.

The MOSC vehicle has three individual elements to be considered: the core vehicle (habitability and subsystem modules), logistics module, and payload module. The logistics module should not require late access as it is relatively inert with regard to internal subsystems. Access to the payload modules and the core vehicle may be required during the prelaunch phase.

The basic MOSC core vehicle center of gravity requires that the habitability module be located in the forward end of the payload bay, adjacent but not attached to the Orbiter docking module. The subsystems module is located at the aft end of the payload bay adjacent to the aft bay bulkhead. In each instance, clearance envelopes are approximately 1 foot, precluding direct internal access to the MOSC in either the horizontal or vertical positions in the Orbiter processing facility (OPF) or at the launch pad. The installation envelope is similar for the logistics and payload modules (see Figure 6-1).

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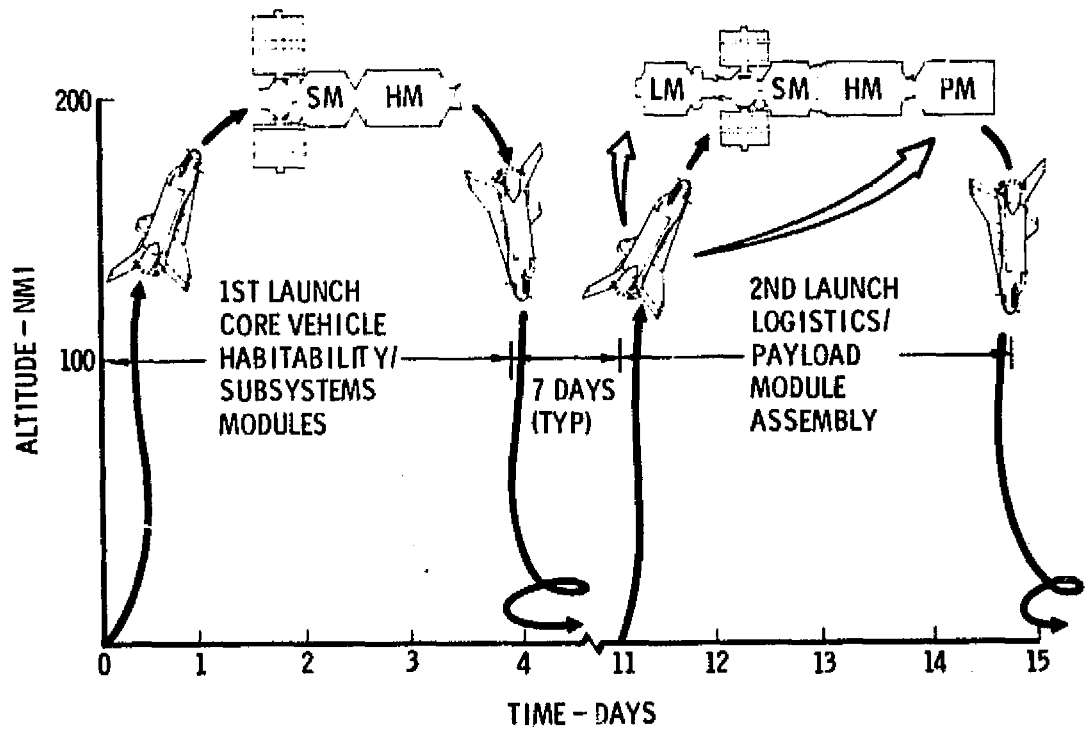

Figure 6-1. Baseline 4-Man MOSC Mission Profile — Orbital Deployment

C.3

Indirect internal access to the habitability module may be possible in the horizontal position at the OPF via the Orbiter crew cabin/docking module. This access capability is considered marginal, however, since the Orbiter docking module and core vehicle docking assembly are not physically connected. Considerable analyses have been performed for NASA with respect to ground access requirements for life sciences payloads which utilize Spacelab hardware of which MOSC is a derivative. Results of these analyses are documented in Report No. CASD/NAS-75-001, February 1975. Access considerations and impact identified in this report are closely comparable to those associated with the MOSC configuration, and a manned airlock hatch in the side of the pressure shell is recommended from a timeline and minimum GSE viewpoint if access is required at the Orbiter processing facility or at the launch pad. The core vehicle has an EVA airlock and hatch located in the habitability module. The EVA hatch is in the end dome at the end away from the subsystem module and should have sufficient clearance to permit limited ingress. The payload module does not have an EVA airlock in the baseline configuration; however, the pressure shell has 1-meter-diameter bolted hatches in the cylindrical section, which could be adapted to an entry port if required.

The MOSC core vehicle and payload modules (except for the life sciences payload) do not require loading of live specimens, and because time-critical stowage items and specimens have not yet been identified, all internal access operations are to be completed prior to MOSC/Orbiter integration.

6.2 LOGISTICS OPTIMIZATION ANALYSES

The operational techniques for Orbiter rendezvous and docking maneuvers are basic in concept and should permit efficient timelines for the initial deployment and buildup of the MOSC vehicle and the resupply mission. During initial orbital deployment operations, the crew would not be on board the MOSC vehicle. The core vehicle subsystems have been conceptually defined to be operational in the unmanned mode, thus the core vehicle can be inserted in orbit and remain stable until the second launch which would bring the crew and the logistics/payload modules. This would occur approximately 7 days after the initial launch, as shown in Figure 6-1.

The initial mission analysis evaluated the Baseline 4-man MOSC (i.e., multiple launch - 5-year orbital life with 90-day resupply logistics) and considered the possible use of a 3-man Limited Duration MOSC mission (i.e., single launch — 60 to 90 days in orbit) with regard to efficiency of accomplishing the candidate payload program. The crew exchange, resupply, and payload replacement mission module recommendations were based upon the most economical operational approach for supporting the defined payload program requiring long-duration missions (>7 days). The analytical approach is illustrated in Figure 6-2.

Each payload combination identified in the payload requirements task was examined to determine whether it was within the Shuttle's payload weight and altitude performance capability. As illustrated in Figure 6-3, each mission can be flown utilizing only the Orbiter integral OMS kit when the payload-altitude range is limited. This approach permits utilization of the total payload bay length. The solid bars in this figure define the altitude range which is acceptable to each payload group. Since the Orbiter's payload-altitude range varies between 100 and 350 nmi, it was arbitrarily divided

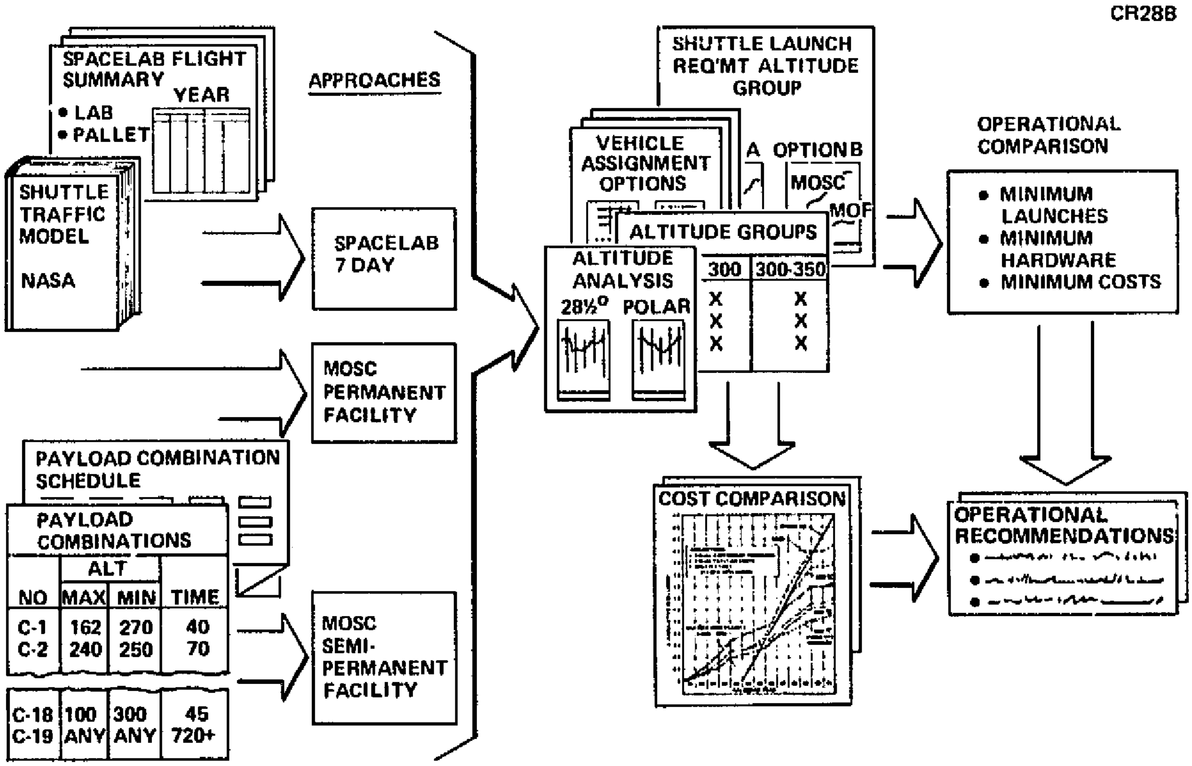

Figure 6-2. Operations Analysis Approach

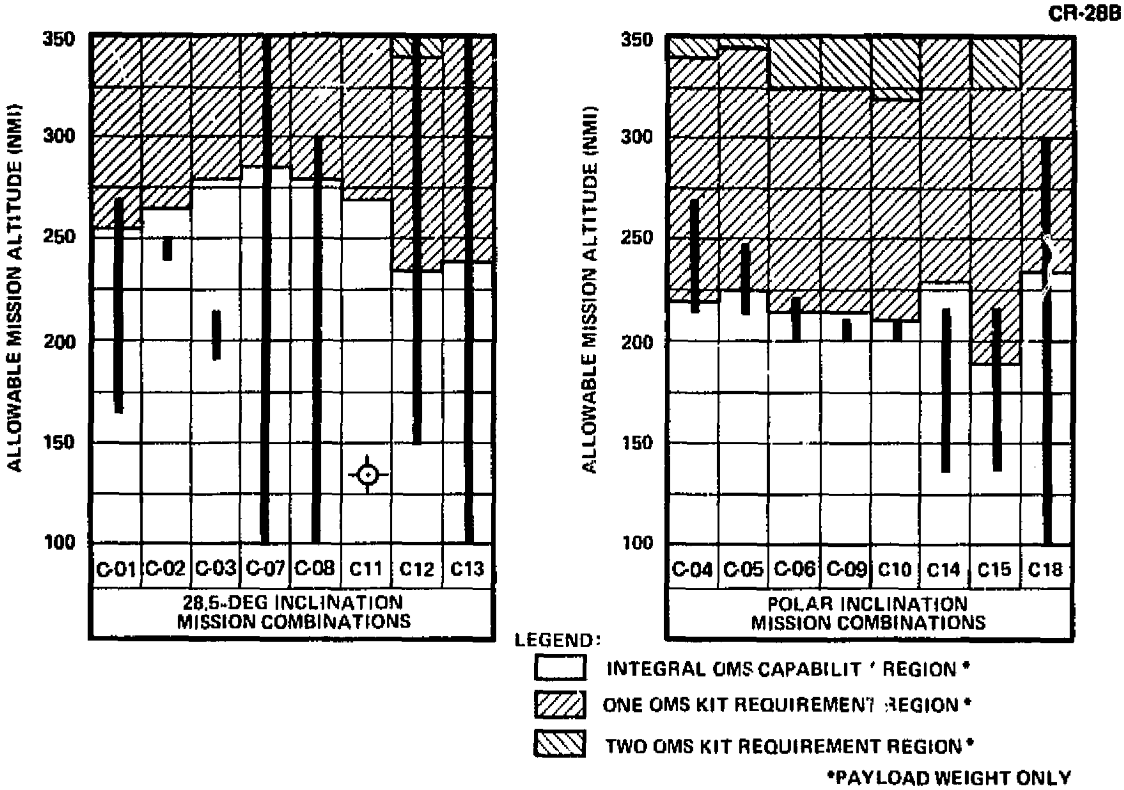

Figure 6-3. Mission Combination Altitude Distribution

into five, 50-nmi increments, shown in Figure 6-4. Each of these increments was analyzed to determine its payload population density, and to identify those payloads that could be assigned to the Baseline 4-man MOSC orbital facilities if they were stationed at a single altitude in 28.5° and polar inclinations. An example of this analysis is given in Figure 6-5 for 28.5° inclination missions. In the 100-to-150 nmi altitude increment (Group 1), four payload combinations (C-07, C-13, C-11, and C-08)can be assigned to the baseline MOSC if it is stationed at an altitude of 135 nmi. The remaining payload combinations can be accommodated by any of the three options as indicated. The primary criterion adopted to select the best option was the least number of STS launches required. The division of launches in terms of a baseline MOSC or a limited-duration MOSC facility for each option of Altitude Group-1 as described in Figure 6-5 is presented in Figure 6-6. Other altitude groups were similarly analyzed.

The preceding analyses in combination with equivalent polar orbit analyses, determined that the minimum number of Shuttle launches necessary to accommodate the reference payload combinations mission schedule was 60, and

MISSION COMBINATION NUMBER	ORBITAL INCLINATION	MISSION COMBINATION ALTITUDE GROUPS (NMI)				
		GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
		100 - 150	150 - 200	200 - 250	250 - 300	300 - 350
C-01	28.5 DEG		X(>162)	X	X(<270)	
C-02	↕			X(>240)		
C-03	↕		X(>189)	X(<216)		
C-07	↕	X	X	X	X	X
C-08	↕	X	X	X	X	
C-11	↕	X(135)				
C-12	↕		X	X	X	X
C-13	28.5 DEG	X	X	X	X	X
C-04	POLAR			X(>216)	X(<270)	
C-05	↕			X(>216)		
C-06	↕			X(<220)		
C-09	↕			X(<210)		
C-10	↕			X(<210)		
C-14	↕	X(135)	X	X(<216)		
C-15	↕	X(·135)	X	X(<216)		
C-18	POLAR	X(>135)	X	X	X	

Figure 6-4. Mission Combination Altitude Groups

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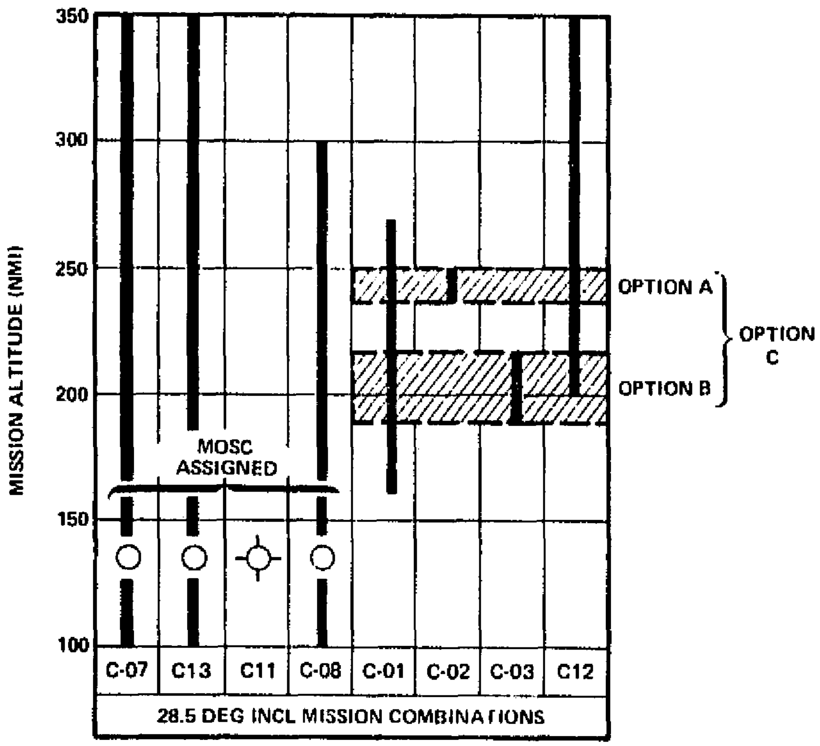

OPTION A:
- ONE MOSC AT 135 NMI
- ONE MOSC AT 240-250 NMI
- ONE MOSC-LIMITED DURATION ACCOMMODATES MISSION COMBINATION C-03

OPTION B:
- ONE MOSC AT 135 NMI
- ONE MOSC AT 190-215 NMI
- ONE MOSC-LIMITED DURATION ACCOMMODATES MISSION COMBINATION C-02

OPTION C:
- ONE MOSC AT 135 NMI
- ONE MOSC-LIMITED DURATION ACCOMMODATES MISSION COMBINATIONS C-01, C-02, C-03, AND C12

Figure 6-5. Altitude Group 1 (28-1/2° Incl) Vehicle Assignment Options

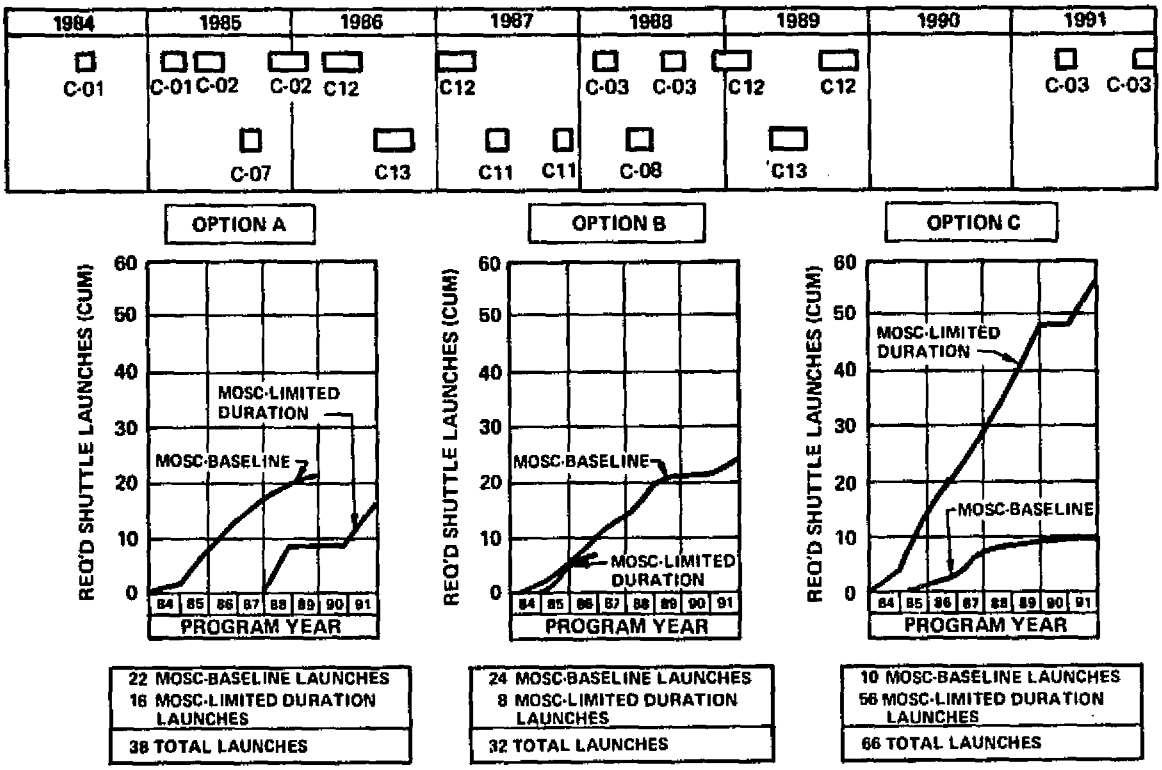

Figure 6-6. Altitude Group 1 (28.5° Incl) Shuttle Launch Requirements

① OTHER ALTITUDE GROUPS WERE SIMILARLY ANALYZED

required three baseline four-man MOSC facilities and one three-man limited-duration MOSC facility.

The analysis determined that two baseline four-man MOSC facilities were required in polar orbit at 200- and 225-nmi altitudes, the first of which supported payload combinations C-06, C-09, C-10, C-14, C-15, and C-18 and the second of which was assigned payload combinations C-01, C-03, C-07, C-08, C-12, and C-13. Because of widely differing altitude requirements, it was necessary to assign one limited-duration MOSC facility to accommodate payload combination C-02 (250 nmi) and C-11 (135 nmi).

As shown in Figures 6-7 and 6-8, these analyses identified a traffic model requiring 60 launches, based on a minimum cost compromise which considered both minimum launches and a minimum number of MOSC vehicles.

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ORBITAL INCLINATION	ALT GROUP	OPTION	MOSC REQ'D LIMIT	MOSC REQ'D BASE	SHUTTLE LAUNCHES REQ'D
POLAR	1	A	1	2	33
	1	B	1	2	33
	1				
	2				
	2				
	2				
	3				
	3				
	4				
	4				
	4				
POLAR	4				

ORBITAL INCLINATION	ALT GROUP	OPTION	MOSC REQ'D LIMIT	MOSC REQ'D BASE	SHUTTLE LAUNCHES REQ'D
28.5 DEG	1	A	1	2	38
	1	B	1	2	32
	1	C	1	1	66
	2	A	1	1	37
	3	A	1	1	43
	3	B	1	1	37
	4	A	1	1	49
	5	A	1	2	43
	5	B	1	2	37
28.5 DEG	5	C	1	1	56

- NO PAYLOAD LENGTH CONSTRAINTS (ONE PAYLOAD = ONE LAUNCH)
- NO ALTITUDE CHANGE CAPABILITY
- NO LAUNCH SHARING (ONE-WAY)

MINIMUM VEHICLES/MINIMUM LAUNCHES

- 60 TOTAL LAUNCHES
- 3 MOSC-BASELINE REQUIRED
- 1 MOSC-LIMITED DURATION REQUIRED

PAYLOAD LENGTH CONSTRAINED
(ONE PAYLOAD ≤ TWO LAUNCHES)
+25 NM/-65 NMI ALTITUDE CHANGE
CAPABILITY

MINIMUM VEHICLES/MINIMUM LAUNCHES

- 69 TOTAL LAUNCHES REQUIRED
- 2 MOSC BASELINE REQUIRED -28.5° AND POLAR

Figure 6-7. Optimization Methodology

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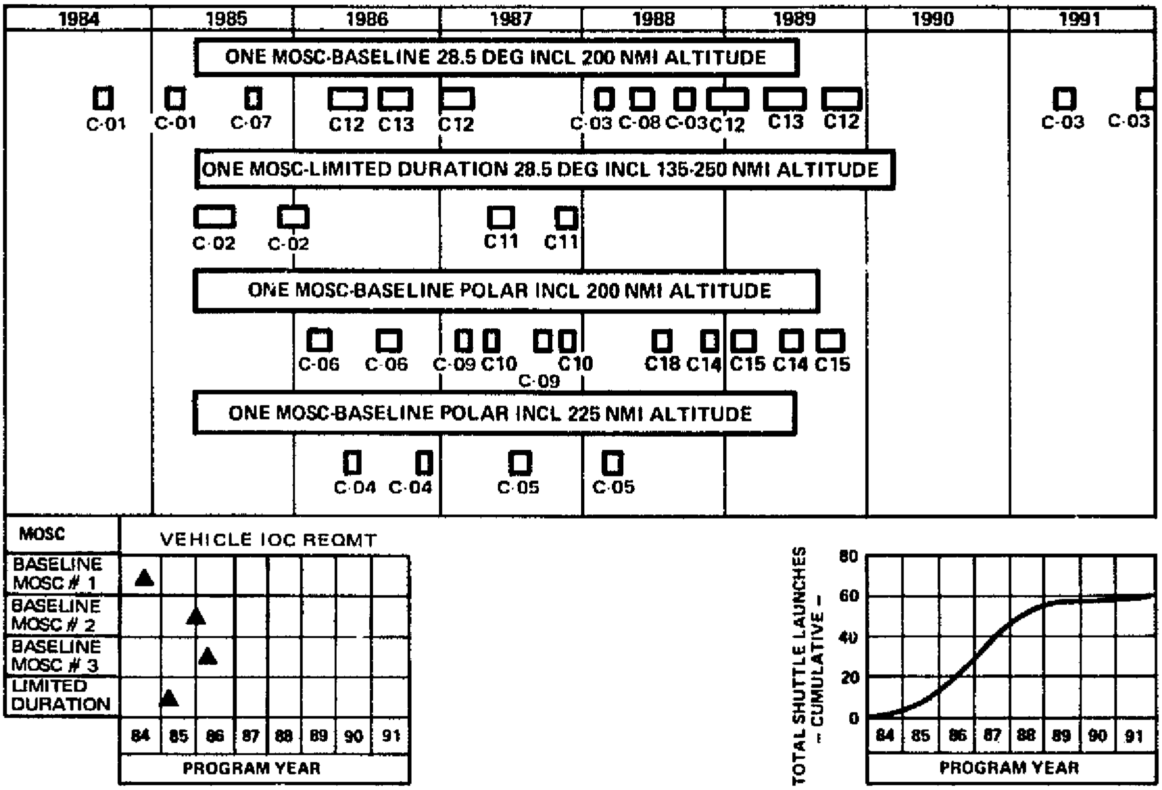

Figure 6-8. Preliminary Minimum Vehicle/Minimum Launches Mission Model

Cargo bay length constraints were not imposed on the payloads in the initial analyses (e.g., it was assumed that C-11 could be delivered and returned in a total of two normal delivery and return launches). Each payload was therefore reexamined with respect to its probable length requirements, based on SSPD data, to determine the effect on total Shuttle launches required. When payload length was constrained by the Orbiter cargo bay, the total Shuttle launches required increased from 60 to 124.

Figure 6-8 reveals that if each baseline MOSC at 200-nmi altitude in the polar and 28.5° inclination orbits could change altitude (±25 and ±65 nmi, respectively), provided either by a logistics module propulsion kit or by the Shuttle OMS, only two baseline MOSC facilities would be required to satisfy the entire payload program.

A trade analysis was conducted to determine the total number of launches required when only two baseline MOSC vehicles were utilized. Three operational concepts were compared, as indicated in Figure 6-9. Operational Concept C resulted in the minimum number of required launches, i.e., 47;

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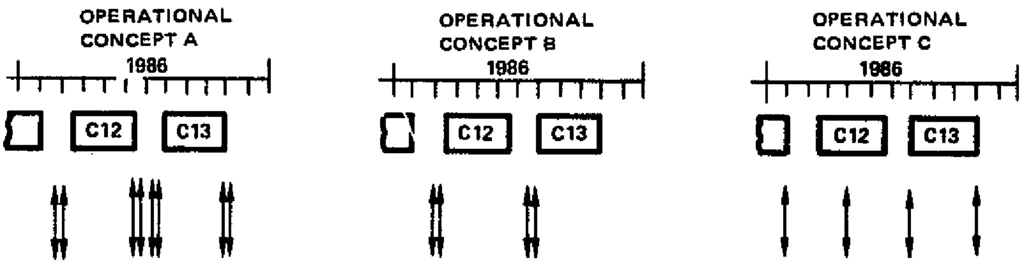

- RETURN PAYLOAD HARDWARE AT END OF MISSION
- 116 LOGISTICS LAUNCHES REQUIRED
- MAX ON-ORBIT CREW TIME = 100 DAYS
- MIN ON-ORBIT CREW TIME = 25 DAYS

- LAUNCH-ON-DEMAND LOGISTICS
- 67 LOGISTICS LAUNCHES REQUIRED
- MAX ON-ORBIT CREW TIME = 180 DAYS
- MIN ON-ORBIT CREW TIME = 45 DAYS

- 90 DAY CENTERS FOR LOGISTICS LAUNCHES
- 47 LOGISTICS LAUNCHES REQUIRED
- MAX ON-ORBIT CREW TIME = 90 DAYS
- MIN ON-ORBIT CREW TIME = 90 DAYS
- REQUIRES RESHAPING PAYLOAD PROGRAM

Figure 6-9. Comparison of Operational Concepts

however, because of the 90-day centers logistics flight schedule, a drastic payload program schedule change would be required. Operational Concept A was operationally desirable, because payloads would be delivered as required, and crew time would be effectively utilized, but 116 Shuttle launches were required. Operational Concept-B was determined to be the most desirable, because the total number of required launches was only 69, i.e., 67 required operationally plus 2 additional for delivery of the core vehicle, even though it required a variation in crew mission time and a maximum crew on-orbit time of 180 days.

As this would at least double the launch costs, an alternative approach of utilizing an altitude change was investigated. This proved very effective inasmuch as only four payloads were identified which would require an altitude change beyond the normal altitude band. Those are C-2 at 240 nmi and C-11 at 135 nmi in 28.5° orbit, and C-4/C-5 at 215 nmi in polar orbit. It was assumed that the Orbiter could accomplish the $\pm$25-nmi change in polar orbit. The $\pm$65 nmi in 28.5° orbit would require either Orbiter or tug support. As this was a limited case, an altitude change propulsion subsystem was not considered for the MOSC vehicle. This subsystem, however, could be added by means of a logistics module propulsion kit.

The results of this operations analysis were applied to the Tasks 2 and 3-vehicle and subsystem selection and definition. The following salient points summarize the mission analysis task:

A. The planned experiment program requiring long-duration missions (>7 days) can be most economically implemented by utilizing two Baseline 4-Man MOSC facilities. The candidate payload program, as defined in Book 2, would be most effectively accomplished by one baseline MOSC stationed in polar orbit at about 200-nmi altitude and a second baseline MOSC stationed in a 28.5° inclination orbit at about 200-nmi altitude. A total of 69 logistics launches should be baselined. These logistics flights would be launched on demand with maximum 90-day centers.

B. Modifying the current candidate payload program permits the lowest-cost operational program implementation approach of two

baseline MOSC vehicles (i. e., polar and 28.5° orbits) which are logistically supplied on 90-day centers.

C. For early and/or special missions supporting experiments which require up to 60-day mission duration, utilization of a three-man limited-duration MOSC vehicle should be considered.

6.3 LOGISTICS-RESUPPLY MISSION ORBITAL OPERATIONS

An evaluation of logistics-resupply operations was made to identify operational options, confirm the MOSC vehicle configuration, and identify the Orbiter rendezvous and docking sequence. An Orbiter logistics resupply mission generally involves crew exchanges and delivery of a logistics module and a payload module to the orbiting MOSC vehicle. It also returns to Earth the previous crew, depleted logistics module, and completed payload module.

The two options which were evaluated for implementing both the orbital assembly operations and the logistics resupply mission are:

A. Maximum Orbiter remote manipulation system (RMS) utilization with Orbiter docking assistance.

B. Maximum Orbiter docking with Orbiter RMS assistance.

The mechanical docking of the logistics and payload modules to the MOSC core vehicle has been assumed to be within the RMS dexterity and load/force capabilities. Also, the dynamic force limitations and structural integrity of the international docking assembly were assumed to be acceptable for the purpose of general operational analyses. It will be necessary in a future study to conduct a detailed design and operational analysis of the international docking assembly and the Orbiter RMS to determine their limitations.

6.3.1 Logistics Mission Module Exchange

Option 1-A — Two Orbital Remote Manipulator Systems

This operational sequence which requires the use of both the basic Orbiter-supplied RMS and an additional payload-chargeable RMS is illustrated in Figure 6-10.

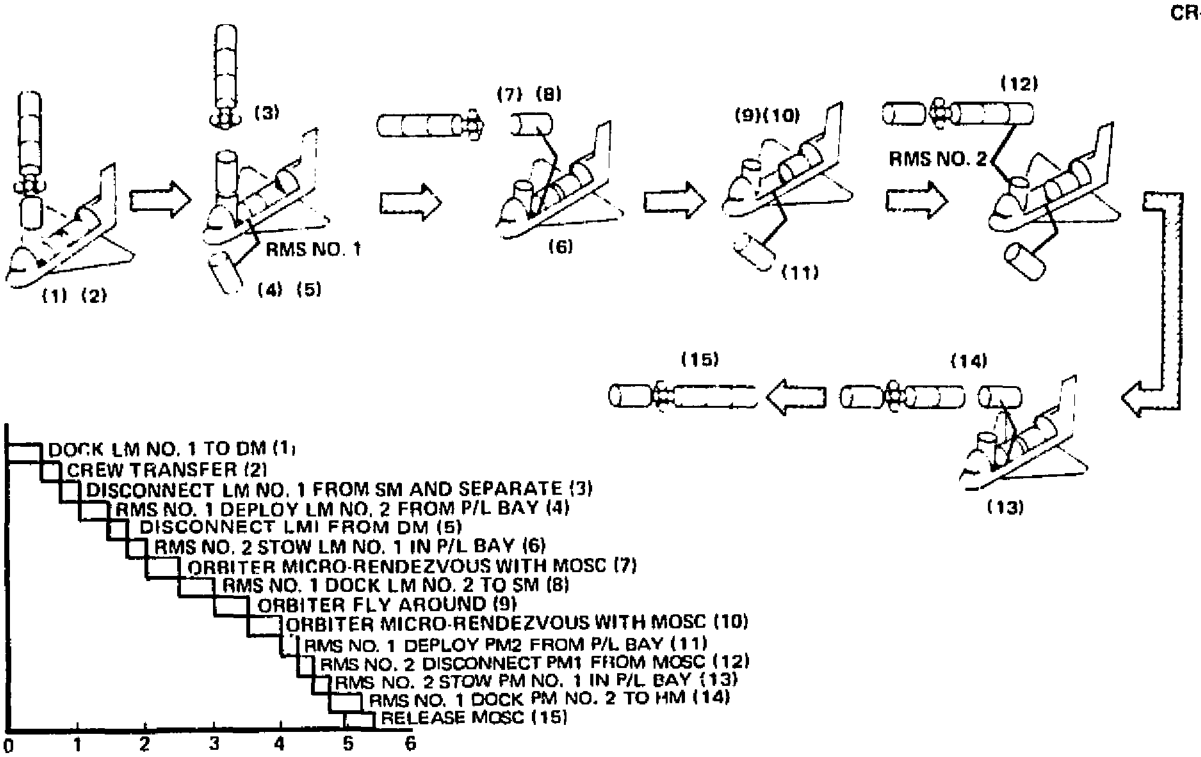

Figure 6-10. Resupply Option 1-A (Two Orbiter Remote Manipulator Systems)

The sequence of events involves crew handover and transfer immediately after the "depleted" logistics module has been hard docked to the Orbiter docking module. After crew exchange is completed, orbital replacement operations on the logistics module and the payload module are initiated, which requires simultaneous operation of both RMS systems. The operation elapsed-time approximations in Figure 6-10 were defined for option comparison purposes only and are not based on detailed operational timeline analyses. Although this option requires the least amount of relative operational time, there are significant operational requirements inherent in the sequence which must be investigated in detail. The disadvantages are noted as follows:

A. A payload-chargeable RMS is required - approximate weight 2,000 pounds.

B. Additional RMS control equipment and software would require modifications to load handling station in the Orbiter crew compartment.

C. Deployment of the replacement logistics module from the Orbiter cargo bay requires that it be positioned out of the field of view of the operator as well as the supplemental payload-bay-mounted TV visual aids. Therefore, the operator is required to handle the module blind, which significantly increases the hazard potential during manipulation operations, or additional visual aids must be provided.

D. Deployment of the payload module from the payload bay - same as Item 3, above.

E. The relatively low acceleration capability of a loaded RMS suggests that docking of a manipulator-attached module to a free-flying MOSC may be marginal due to the engagement forces required by the international docking assembly.

6.3.2 Logistics Mission Module Exchange Option 2-A — Orbiter Hard Docking

The operational sequence for Option 2-A, illustrated in Figure 6-11, requires the use of only the Orbiter-supplied RMS and docking module. Module replacement operations would require about 10 percent additional time and are accomplished in a "hats-on/hats off" mode.

The MOSC operational considerations are that four MOSC/Orbiter hard-dock maneuvers are required and the new crew must be aboard the MOSC during module exchange operations.

6.3.3 Logistics Mission Module Exchange Options 2-B and 2-C

Two additional options (2-B and 2-C) illustrated in Figure 6-12 and 6-13 were assessed to determine the required sequences to affect crew handover/exchange either as late as possible or only after modular exchange had been accomplished.

In Option 2-B, the original crew is required to remain aboard the MOSC during modular replacement, whereas in Case 2-C, crew exchange and handover is performed immediately after the initial docking operation. After

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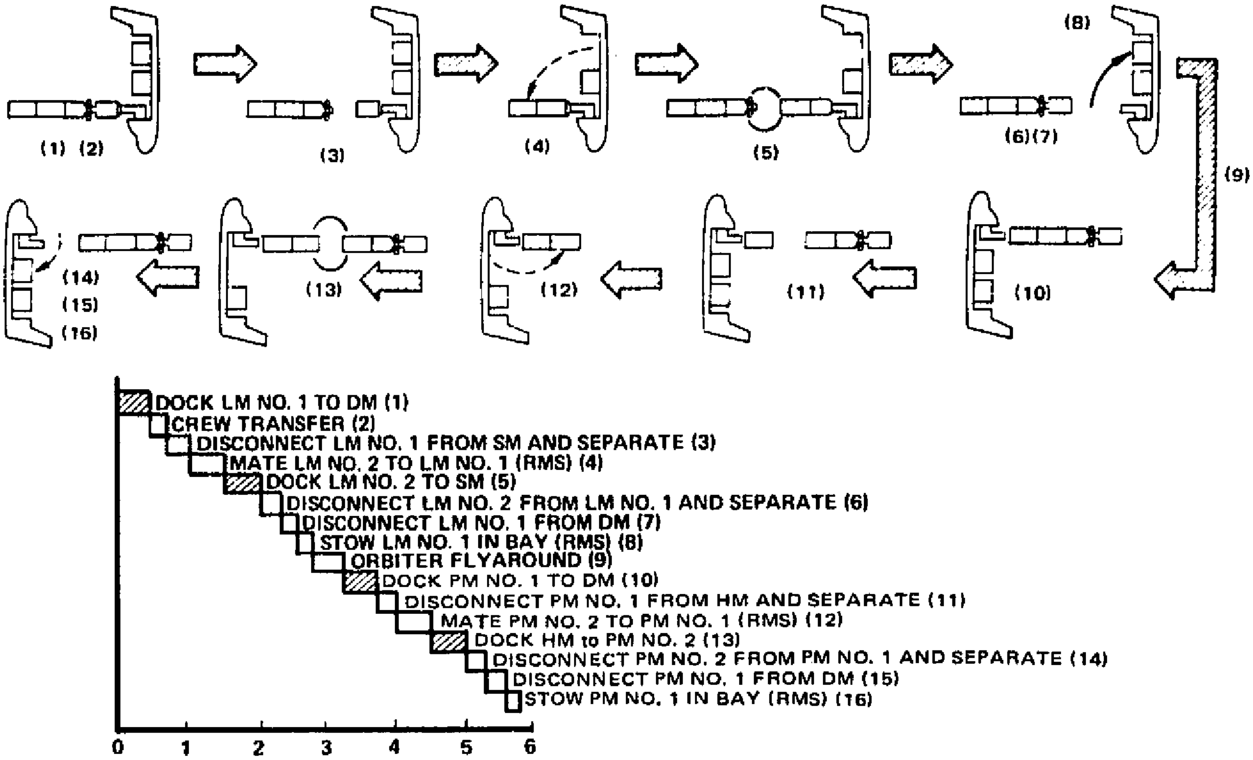

Figure 6-11. Resupply Option 2-A (Crew Transferred to MOSC During Initial Docking)

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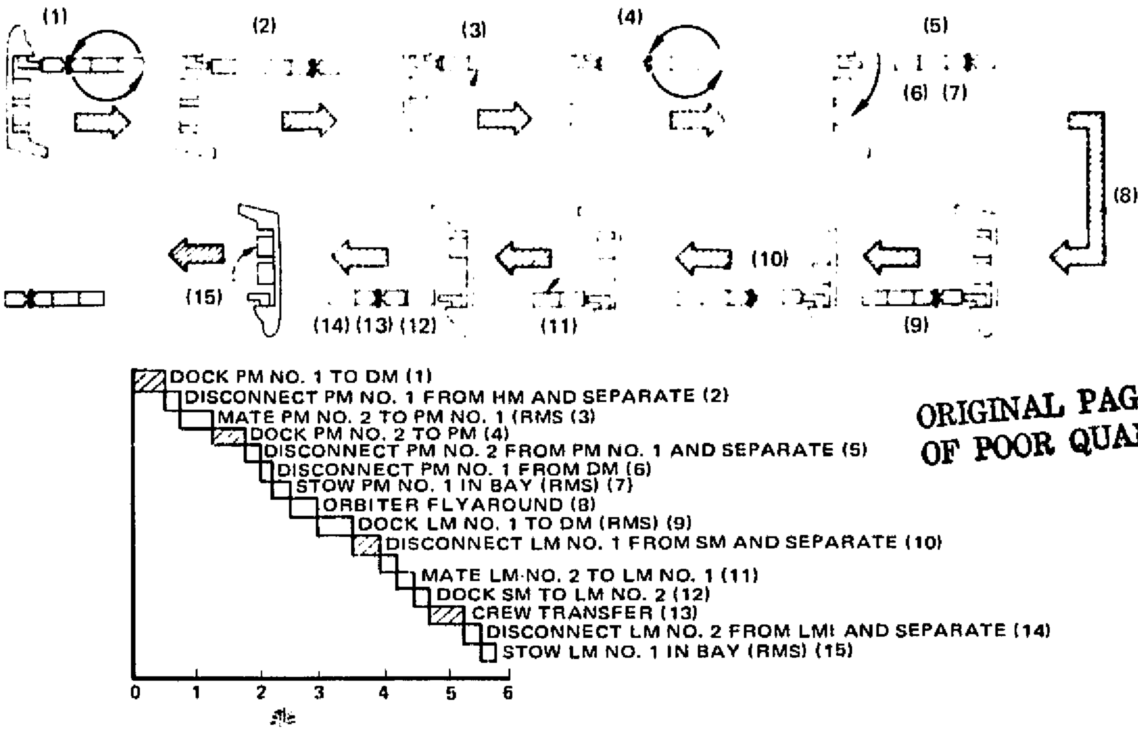

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Figure 6-12. Resupply Option 2-B (Crew Aboard Orbiter During Module Exchange)

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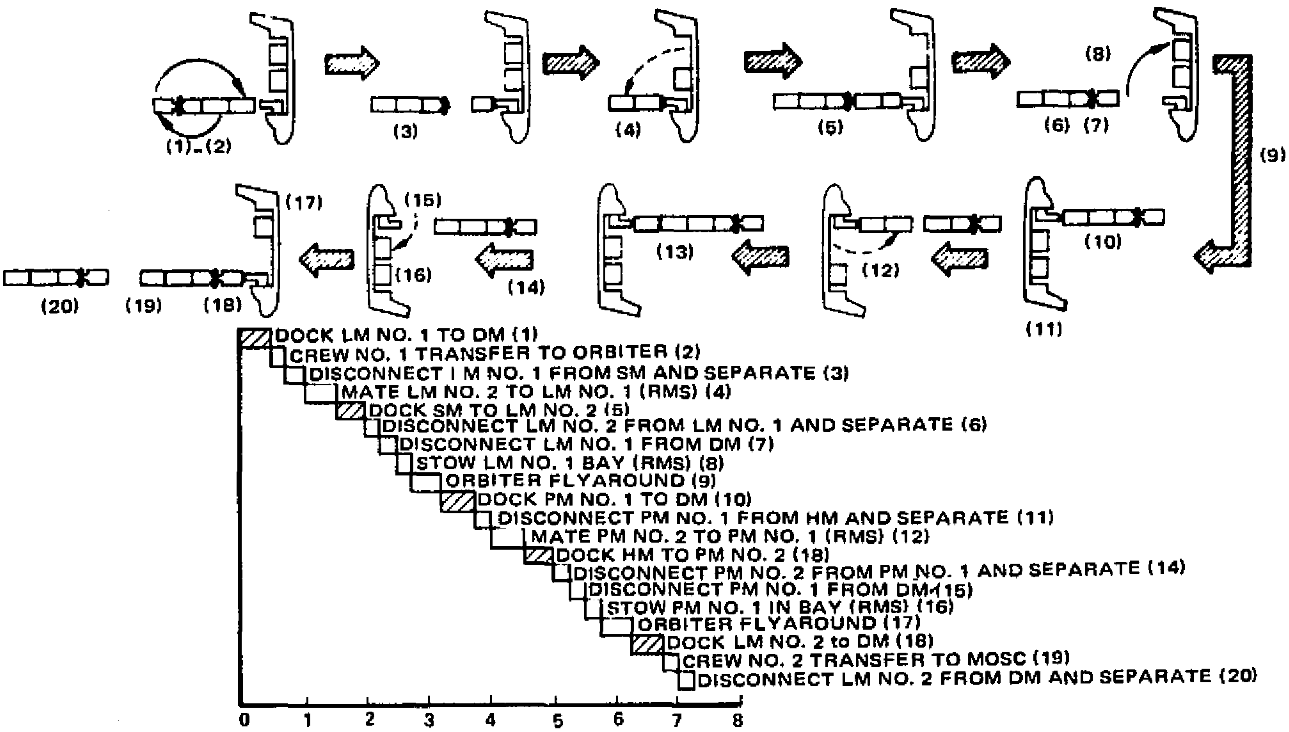

Figure 6-13. Resupply Option 2-C (Late Crew Transfer)

handover has been accomplished in Case 2-C, both MOSC crews exit to the Orbiter via the docking tunnel. after which module exchanges are performed. Upon completion of module exchange, the new crew enters the MOSC via the docking tunnel, and the MOSC is separated from the Orbiter.

The required operations for these options are essentially the same except that Option 2-C required the most relative time (i.e., 40 percent more than Option 1-A) and five hard-docking operations are required (as opposed to four for Options 2-A and 2-B.

6.4 ANALYTIC RESULTS

Although requiring more operational time, Option 2-C was selected as the most desirable operational approach to implementing the MOSC logistics resupply mission since it retains the favorable feature of Option 2-A and 2-B (no requirement for a second RMS), and offers the following additional beneficial characteristics:

A. MOSC systems can be essentially powered down during module exchange since no crew is aboard.

B. MOSC solar arrays may have to be retracted prior to the module exchange operations due to Orbiter thruster plume impingement. In this option the potential requirement for electrical power augmentation can be eliminated if the systems can be powered down. If not, auxiliary battery power can be utilized.

C. Crew safety during the complex module exchange operations is enhanced since the entire crew is located in the Orbiter.

D. Maintaining the crew in the Orbiter during logistics operations reduces the need for logistics module life support consumables requirements by about 7 hours.

6.5 VEHICLE ASSEMBLY AND MODULE REPLACEMENT SEQUENCE

The detailed sequences of module handling and docking requirements for typical operations during the initial vehicle assembly and logistics resupply are included to provide detailed definitions of the preceding operational options. Figure 6-14 depicts the typical initial orbital deployment of a Baseline 4-Man MOSC vehicle. Figure 6-15 portrays the resupply mission replacement of the logistics modules.

After the vehicle assembly or module replacement sequences are complete, the crew will transfer to the MOSC from the Orbiter. Transfer of supplies and materials from the logistics module to the other modules will be performed manually during flight by the crew members as required. In general, it is anticipated that the payload modules would be exchanged or assembled first, with the logistics module containing the consumable supplies being the last element to be exchanged before manning and reactivation of the complete system. The final decision on the operational assembly sequence, however, will be dependent upon the mounting provisions in the Orbiter cargo bay and, because of certain peculiar payload characteristics, the sequence may vary from flight to flight.

Interviews with Skylab astronauts suggested the desirability of providing a crew overlap period of several days for debriefing and information exchange between the returning crew members and the replacement personnel. If such a transfer period is required, the Orbiter may be required to remain either attached or in the vicinity of the MOSC for this checkout and transfer period.

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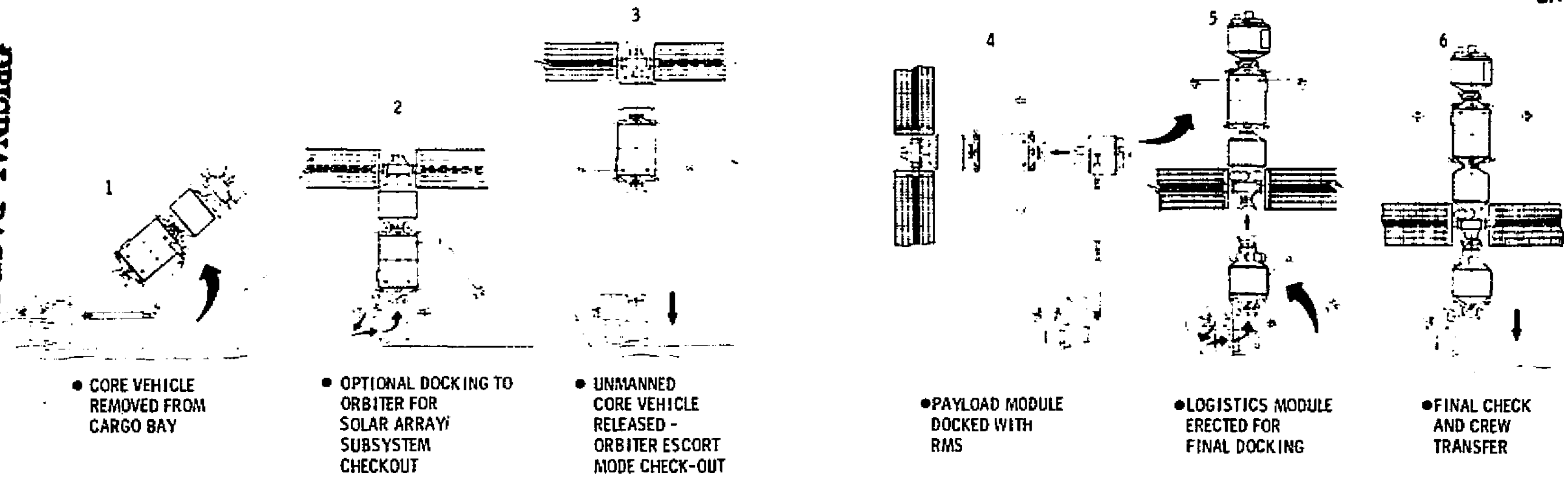

Figure 6-14. Baseline 4-Man MOSC, Initial Orbital Sequence, First Launch, Core Vehicle Deployment

Second Launch – Logistics/Payload Module Deployment

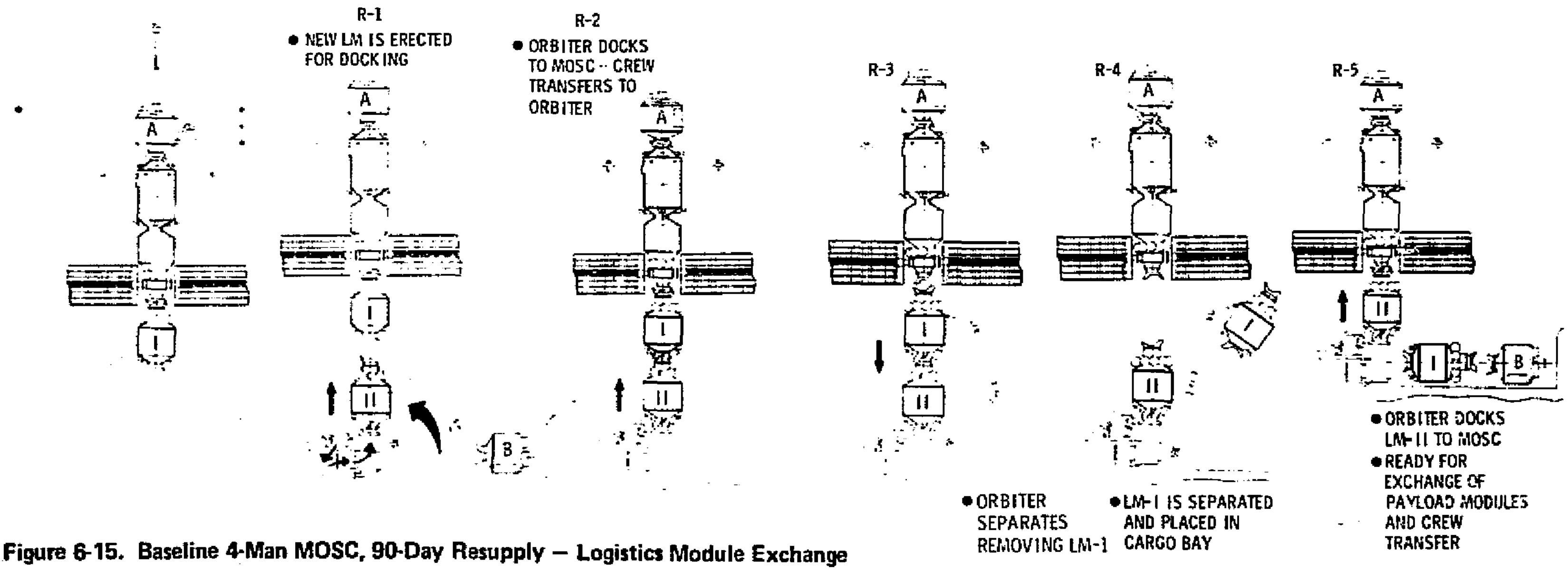

Figure 6-15. Baseline 4-Man MOSC, 90-Day Resupply – Logistics Module Exchange

Section 7
EVOLUTIONARY PLAN FOR FUTURE MISSIONS

The capability to support future missions requiring greater scientific and applications program support can be readily provided by the MOSC modular concept. As shown in Figure 7-1, a logical progression of space station growth could occur between 1985 and 1995.

7.1 VEHICLE CONCEPTS AND MISSIONS

The initial missions for the Baseline 4-Man MOSC facility will be in a 28.5° orbit and will consist of multidiscipline orbital-research programs. These missions may also include space structure assembly projects in which large assemblies such as radio telescopes are assembled manually and then moved to the desired operational orbit by unmanned tugs. The initial facility will

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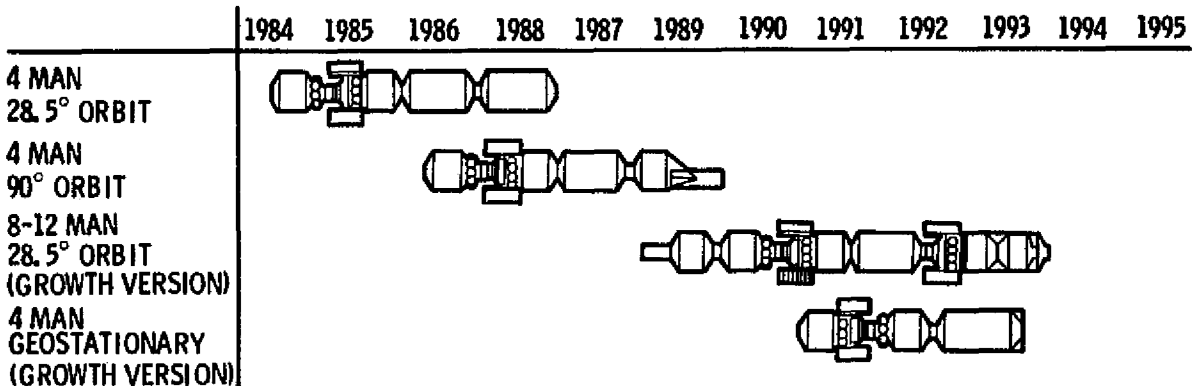

PAYLOAD TRAFFIC		1984	1985	1986	1988	1987	1989	1990	1991	1992	1993	1994	1995
SSPDA	SCIENTIFIC	1	3	2	3	4	5	1	2	1			
	APPLICATIONS		1	2	4	2		1	1	1	1	1	1
	COMBINATIONS			2	1	1							
NEW	MANUFACTURING						1	1	1	1	1	1	1
	SERVICING								1	1	1	1	1
	STRUCT ASSY							1		1			

Figure 7-1. Representative MOSC Program Operations

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have flexible accommodations/subsystems to support a full span of scientific and technological projects. Approximately 2 years after the initial system is operational, a second facility can be locatec. in polar orbit. The basic core facility can grow easily into an 8- to 12-man fi.cility by adding modules as the demand for orbital activities grows. The 28.5°and polar facilities will be supported by Orbiter launches from KSC and from VAFB.

The versatility and effectiveness of the MOSC modular elements are illustrated by the modular configurations which can meet a variety of mission and payload requirements. The growth into the regime of higher electrical power, 20 to 24 kW, and the larger crews of 6 to 12 would require serious consideration of a docking adapter module to keep the total vehicle length to a minimum. This would benefit both the crew activity and the inherent structural rigidity by reducing bending moments and resultant effects on the stability and control system.

The 12-man option shown in Figure 7-2 could evolve from the baseline configuration with the addition of a small-diameter docking adapter module. An alternate radial docking concept using a three-cylindrical-section habitability module is shown in Figure 4-9. The habitability/docking module would also be a candidate for the growth version. Safety procedures, traffic flow, and area volume assignments require detailed analysis to assess the relative merits and make a selection.

The orbital buildup of the various options would start with the baseline four-man vehicle. However, in each option, module rearrangement and additions could convert the vehicle to an option to support a different major objective.

Three typical evolutionary paths are depicted in Figure 7-3. Path 1 is the study baseline concept defined in Section 5. This approach has the advantage of developing the basic core vehicle as a point of departure for developing various mission support configurations. Preliminary evaluation determined that a four-man crew was feasible for assembling large structures in space and the conduct of the science and applications program defined in the MOSC Study. Planning for eventual growth to a six-man crew could be accomplished with minimum modification by selectively oversizing subsystems for six men.

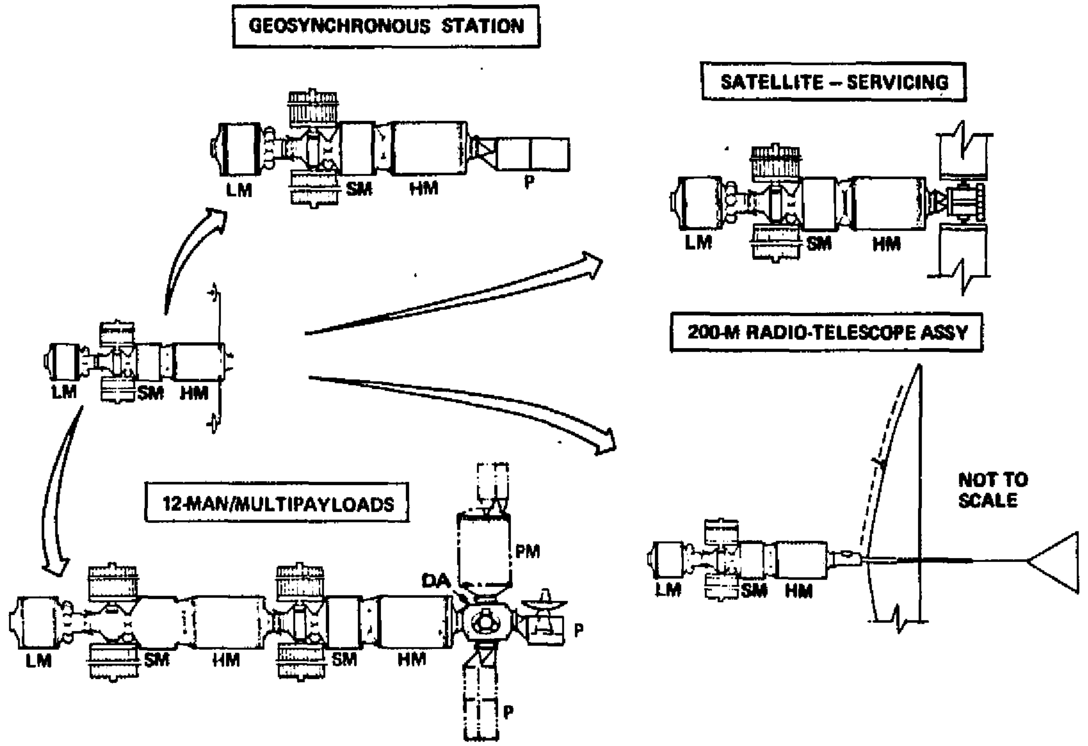

Figure 7-2. Future Mission Aspects – Growth Options

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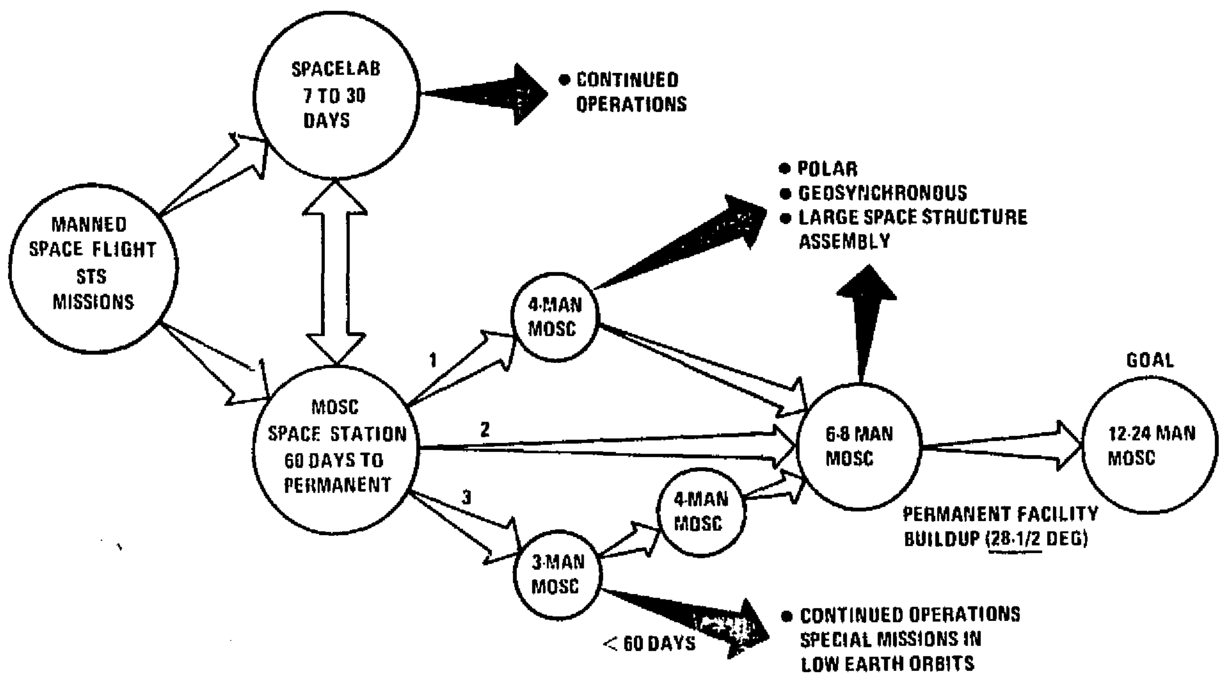

Figure 7-3. Space Station Alternative Evolutionary Paths

This would not require that the added consumables or components be installed for the four-man baseline, but interfaces would be installed and mounting envelopes provided. In this approach, a modified logistics module could accomodate the two additional crewmen. This variation has the inherent flexibility of adjusting the crew size between four and six as a function of payload operational requirements and at the same time not overly penalizing the core vehicle.

Path 2 leading directly to the six-man configuration has several options, which are described in Appendix F. These include a direct modification to the baseline four-man habitability module, a longer habitability module, or a docking adapter module with an additional habitability or combination module.

A direct modification to the baseline four-man concept has the disadvantage of eliminating the wardroom and some free volume in order to make space available for the two additional crew quarters.

Path 3 is an austere approach which could support a limited scientific and applications program in low Earth orbit, but would require significant modifications for growth to a four-man vehicle.

7.2 ASSEMBLY OF LARGE STRUCTURES IN SPACE

This potential future mission was selected for preliminary analysis to confirm the versatility and support capability inherent in the MOSC concept.

The Apollo and Skylab programs have demonstrated that an operational extravehicular activity (EVA) capability can play a significant role in future space missions. An EVA capability is planned for Orbiter support, as well as its payloads. An operational manned maneuvering unit (MMU) is an established Orbiter program requirement. It can be anticipated that future manned orbital facilities will draw on this basic EVA technology development to significantly expand their operational capability.

One area in which the utilization of EVA crewmen can play a major role is the erection of large structures in space. Large antennas for communication and radio telescopes, large solar energy collectors (both thermal and electrical)

and large platforms for grouping multi-antenna arrays are projects which can be reasonably foreseen in the 1980-1990 time period. The size of these structures will range from 100 to 1,500 feet in span. This does not imply a limit for future projects, but only serves to bound this discussion of potential projects.

Since the Shuttle payload bay is 60 feet long, it is obvious that these large structures will require deployment or assembly in space.

Erection techniques will undoubtedly range from fully automatic deployment to fully manual with the majority being a combination of these approaches. Some of the more significant parameters involved in considering the utilization of EVA crewmen in assembling large structures in orbit are described in the succeeding paragraphs.

7.2.1 EVA Crew Timelines

In assessing EVA crew time, it is necessary to consider the support time in addition to the time actively spent in EVA. A typical EVA consists of pre-EVA, EVA, and post-EVA activities. The following times are based largely on NASA-JSC assessments of EVA capability for Shuttle.

Preparing for EVA will consist primarily of prebreathing (unless future EVA suit pressures are raised to preclude this), a planning session, equipment preparation, suit donning, life support equipment donning, equipment checkout, airlock depressurization and vehicle egress. These operations will require approximately 2 hours per man per EVA operation. Three hours of prebreathing are required, but can be done simultaneously with other EVA and non-EVA tasks.

Portable life support systems for EVA are being designed for 6-hour (maximum) operations. Apollo and Skylab experience, plus projected equipment improvements, tend to make a 6-hour EVA operation realistic on a repetitive basis. A reasonable assumption for large-structure-erection missions would be one 6-hour EVA per man per day for 4 days out of 5.

Current safety guidelines require an IVA crewman to act as monitor during all EVA operations. This adds 6 to 7 manhours per EVA operation. This requirement should be re-evaluated, however, when considering long-term-operation EVA missions.

Post-EVA activities consist of vehicle ingress, airlock repressurization, suit and support equipment doffing, recharging life support units, and stowage of equipment. These tasks will require approximately 1.5 hours per man per EVA operation.

Table 7-1 shows that for a two-man EVA team, 48 manhours of actual EVA are available every 5-days. During this 5-day period, 100 manhours of crew time is expended for all EVA-related activities (not including maintenance of EVA systems). By way of comparison, the Skylab mission (SL-3) obtained approximately 27 manhours of actual EVA for a total 114 manhours of EVA-related activity. Although some of the assumptions will need confirmation,

Table 7-1

ASSEMBLY OF LARGE STRUCTURES IN SPACE
EVA MAN-HOURS

	Man-hours				
	Pre-EVA	EVA	EVA Monitoring	Post EVA	Total
Crewman No. 1	2	6		1.5	9.5
Crewman No. 2	2	6		1.5	9.5
Monitor			6		6
Totals	4	12	6	3	25

Actual EVA:

4 days x 12 man-hours/day $= 48$ man-hours

Avg Man-Hours/Mission Day $= \frac{48}{5} = 9.6$ man-hours

Total EVA Related:

4 days x 25 man-hours/day $= 100$ man-hours

Avg. man-hours/mission day $= \frac{100}{5} = 20.0$ man-hours

overall, these are reasonable data points for analyzing large-structure-erection missions. Further effort, however, is required to more precisely define expected EVA timelines and to investigate ways to increase actual-EVA-to-total-EVA-related time ratios.

7.2.2 EVA Equipment

Basic EVA hardware such as pressure suits, portable life support units, manned maneuvering units, restraints, and remote manipulator units are currently in the Shuttle program. Each has extensive development history and can be considered in assessing the erection of large structures in orbit.

7.2.3 EVA Activities

The EVA crewman's role in supporting the erection of large structures in orbit will consist of assembly, transportation, alignment, inspection, checkout, and maintenance. Trade studies will be required to define optimum utilization of the EVA crewman.

7.2.4 EVA Consumables

EVA support of a large-structure assembly would inherently require EVA operations an order of magnitude greater than those of other types of missions being considered for MOSC. EVA operations have significant penalties which are event oriented rather than duration oriented. An example of this is airlock cycling. One airlock depressurization and repressurization is required for each EVA excursion. Missions requiring relatively few EVA operations can afford overboard dump of the airlock atmosphere with subsequent replenishment from vehicle stores. For missions requiring daily EVA operations, a system for airlock atmosphere recovery through pumpdown and storage must be considered. A 90-day mission with daily EVA would consume roughly 1,000 pounds of O_2/N_2, plus tankage, if a pumpdown and storage system were not used. However, a pumpdown and storage system for the airlock will have inherent development, power, and storage requirements. Increased time for airlock depressurization with a pumpdown system must also be considered.

Prebreathing penalties (O_2 consumption) are amplified in a high-EVA-rate mission. Development of a pressure suit which does not require prebreathing

or suit purging could save approximately 630 pounds of O_2 for a 90-day mission, assuming a two-man EVA team.

Another consumable which becomes significant is the water utilized by the portable life support system for body cooling. This amounts to 1,440 pounds for a 90-day mission with daily EVA. Alternate cooling methods might be more attractive where fuel cells (available water) are not used for vehicle power.

7.2.5 Assembly of Large Structures

Assembly should be done on the ground up to the point where the structural density matches the maximum payload density of the Orbiter. Assuming full utilization of the volume available, this would be about 6.2 lb/ft^3.

Orbital assembly can then be accomplished by automatic deployment, EVA crew operations, remotely controlled manipulator arms, remotely controlled free-flyers, or any combination of these. In some applications, such as a large-aperture radio telescope, an automatically deployed core section may be activated initially with the subsequent manual installation of the remaining antenna elements.

Precise definition of assembly techniques requires detailed trade studies for each particular structure. However, it is quite possible that a "universal" structural element can be developed that will be the basic building block for a wide variety of structures.

Assuming a basically manual EVA approach to assembly, several variations are possible:

A. Join ready-made elements to form a complete structure.
B. Assemble elements from basic pieces (e.g., tubes, fittings) and joint elements to form a complete structure.
C. Deploy collapsed elements and rigidize with fasteners; then join elements to form a complete structure.

Orbital assembly of elements from basic pieces is probably not cost effective since this can be done on the ground without exceeding the optimum Orbiter cargo bay payload density (6.2 lb/ft^3).

7.2.6 Role of MOSC

The unique feature of MOSC is its capability for long-term orbital stay time. The Orbiter will have a limited time on orbit and a limited work area. A large structure deployed from the Orbiter only has to be mostly automatic because of the short orbital stay time. On the other hand, structural elements delivered to a MOSC, by periodic Orbiter flights, could be designed for manual assembly, and therefore have a much higher packaging density.

An ancillary module, as shown in Figure 7-4, could be attached to MOSC to provide a work station specifically designed for assembly and deployment of structural elements by EVA crewmen. The module could contain assembly equipment, hand tools, crew restraints, maintenance equipment and alignment verification and adjustment equipment. Remotely controlled manipulator arms could also be part of this module if required.

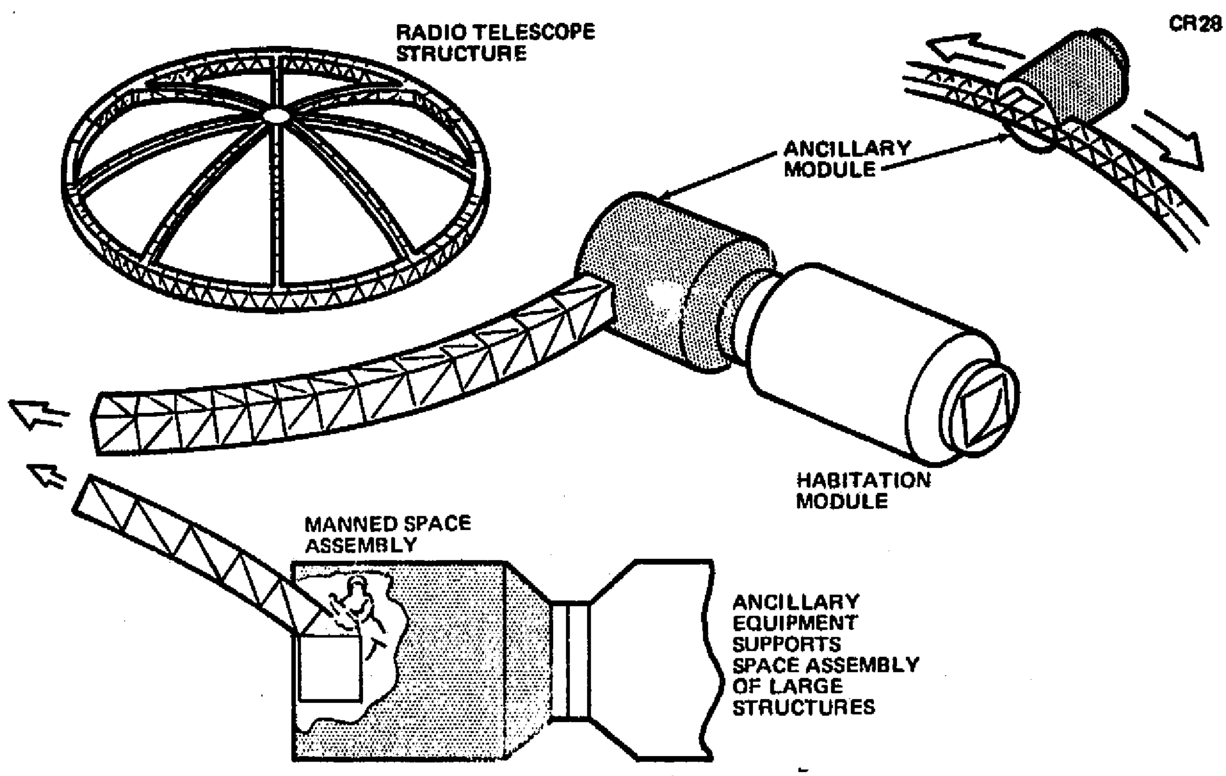

Figure 7-4. Structural Assembly in Space

7.2.7 Large-Structure Assembly-Timeline

In order to provide a quantitative definition of the mission time to manually erect a large structure in space, the assumptions in Table 7-2 were formulated. A 200-m-diameter radio telescope was selected as representative of a typical potential project and has been the object of other studies*. The antenna was assumed to be assembled in low Earth orbit, utilizing the MOSC vehicle for interim attitude control and station keeping, as well as habitability support for the erection crew. After assembly and checkout, the antenna would be moved into its operational high Earth orbit by a Space tug.

The general configuration of the antenna attached to MOSC prior to assembly and deployment is shown in Figure 7-5. The logistics pallet and the docking adapter would be docked to the MOSC. The pallet contains all the structure and assembly jigs for the antenna. The docking adapter contains the operational attitude control subsystems, the electronic subsystems, tools, and other support items. The basic elements of the antenna are shown in Figure 7-6. One possible assembly sequence is shown in Figure 7-7. The deployed antenna, still attached to the MOSC, is shown in Figure 7-8. In order to form the parabolic reflector, the element size and shape would have to vary from row to row. However, to simplify the analysis an average element will be considered. The average reflector element could be a triangular-shaped structure, 20 feet on a side and 2 feet thick. Each element would be collapsed for launch. This increases element density to make optimum use of the Orbiter payload bay. An assembly jig would be set up on the work platform to ensure accurate geometric alignment after each element is unfolded and stiffened by the addition of several structural members. The reflector surface, which consists of fine wire mesh encased in Mylar or other thin film, would be preattached to the one face of the element. Unfolding and locking the element would stretch the wire mesh laminate across the surface. A second layer of laminate would be attached to each element to be used in subsequent reflector assembly. The stiffening members could be attached to the element with hand-held power guns that install pin fasteners in one operation. The assembly jig would be readjusted for each change in element geometry to closely control the parabolic shape

*"Orbital Assembly and Maintenance Study - Midterm Briefing," Martin Marietta, Contract NAS8-14319.

Table 7-2

ASSUMPTIONS FOR ASSEMBLY OF LARGE STRUCTURE IN SPACE

ASSUMPTIONS

- LARGE SPACE STRUCTURE – THE 200-METER CONCEPT WAS SELECTED AS TYPICAL
- LOW EARTH ORBIT
  - MASS 25,000 LB
  - ALTITUDE 200 NM – ASSEMBLY
  - ASSEMBLY PROCEDURE – MANNED
  - ASSEMBLY SUPPORT – MOSC LLS ASSEMBLY MODULE
  - STABILIZATION AND CONTROL – MOSC
- HIGH EARTH ORBIT
  - OPERATIONAL ALTITUDE – 8,000 NM
  - ORBITAL TRANSFER – TUG
  - STABILIZATION AND CONTROL – LSS INTEGRAL SUBSYSTEM

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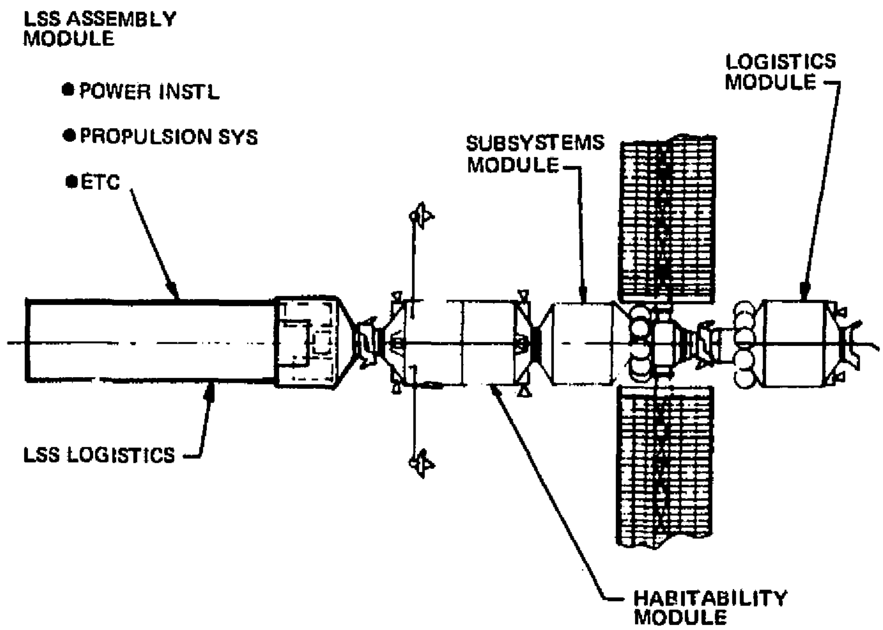

Figure 7-5. 200 Meter Antenna Basic Elements

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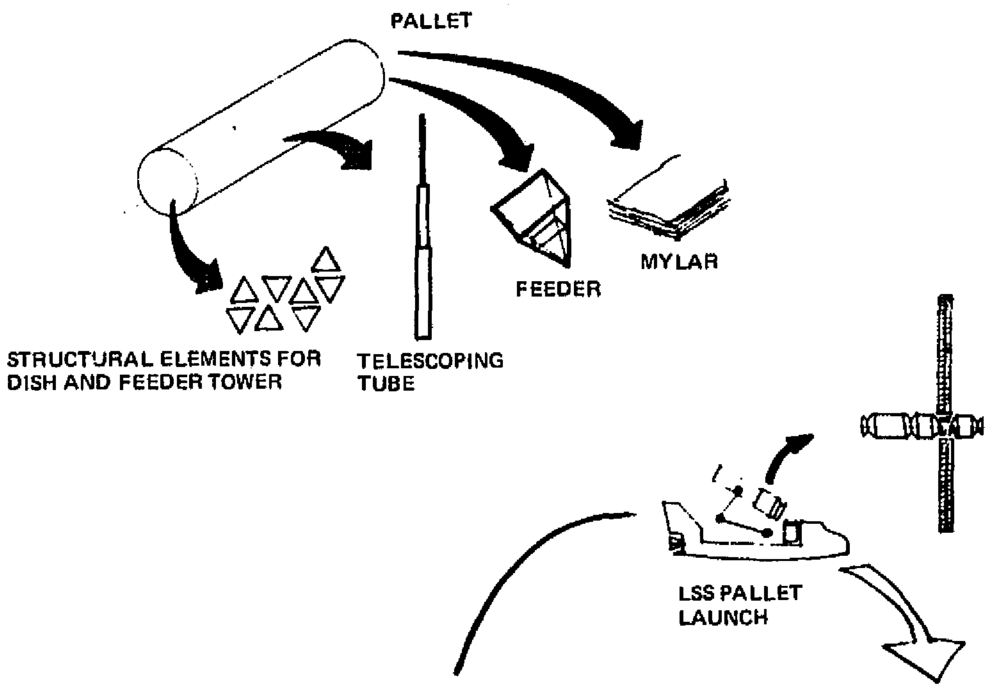

Figure 7-6. MOSC Vehicle Large Space Structure (LSS) Assembly Configuration

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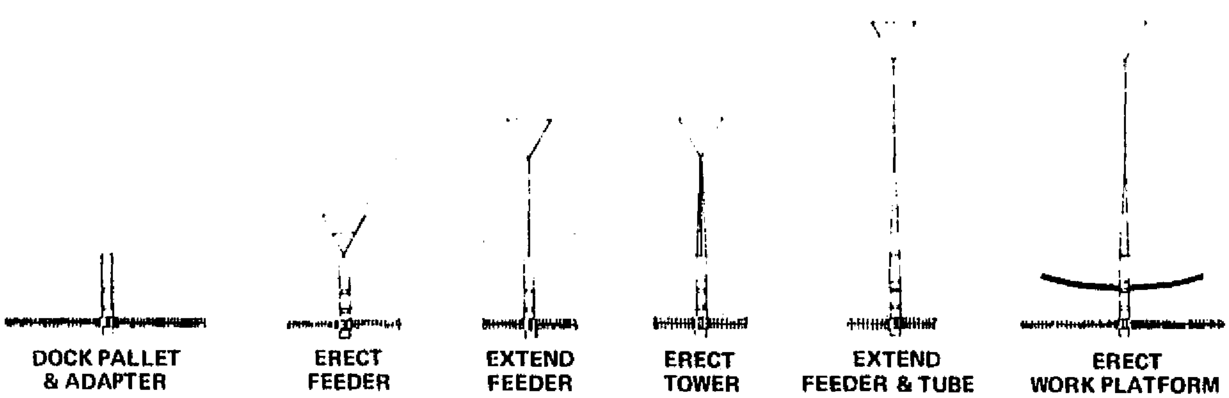

Figure 7-7. 200-Meter Antenna Assembly Sequence

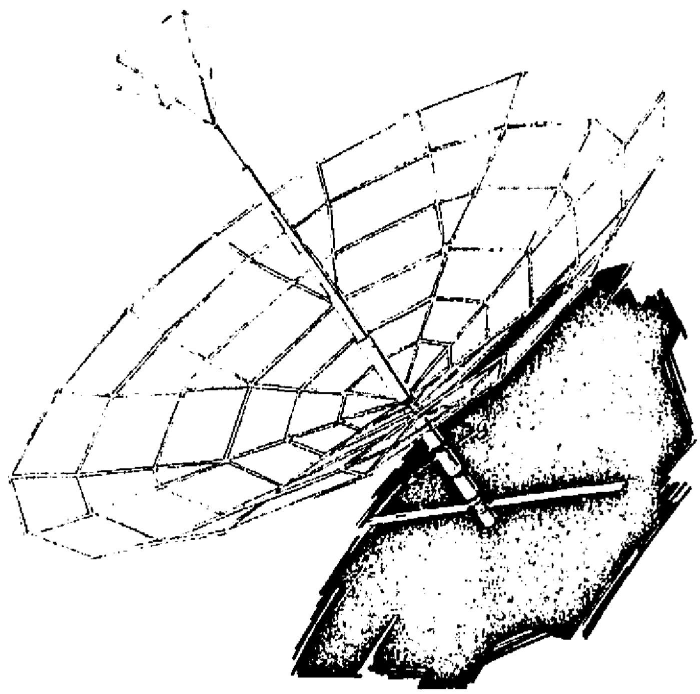

Figure 7-8. Deployed Antenna Attached to MOSC

of the reflector as it grows. After the element was rigidized, it would be removed from the jig and transported to its unique circumferential position on the reflector by the two crewmen.

The mast with its feeder could be assembled either before or after the reflector is assembled. In either case, the logistics pallet could become the first 40 feet of the mast. The feeder is assembled at the end of the pallet and deployed on the end of a 120-foot telescoping tube stowed in the center of the logistics pallet. The mast is aligned by adjustments at the tower/pallet interface.

Final assembly operations consist of relocating attitude control units from the docking adapter out to positions on the reflector, and erection of solar power panels. During checkout of the antenna system, some EVA would be required to adjust structure or support modules.

Table 7-3 summarizes the time required for the orbital assembly of the 200-meter radio telescope.

The time estimate was based on the following assumptions:

A. Erection technique basically manual.

B. Four-man crew with two men on EVA team, third man monitors EVA team during EVA, and fourth man dedicated to non-antenna tasks.

C. Life support provided by portable units.

D. Average of 9.6 manhours of EVA available per mission day (see Table 7-1).

E. Rest periods requiring 5 minutes out of every EVA hour.

In addition to the 75 days required for actual assembly, about 10 days of checkout and adjustment would be required. Allowing time for contingencies, such as repair, a mission length of about 90 days would be required.

Reallocating existing crewmen or increasing the overall crew size, to increase the number of crewmen involved in assembling the telescope has nearly a linear effect on assembly time. For example, using a third crewman to provide a daily two-man crew would give a 12 manhours-per-day EVA capability, and using five men of a six-man crew to provide two shifts of two men daily would give a 24 manhour-per-day EVA capability. The latter case would cut the actual assembly time to 30 days. However, it is not obvious that maximizing the number of crew dedicated to telescope assembly, versus a mixture of erection and scientific experimentation, is the best approach.

Varying the assembly technique from fully manual to fully automatic would greatly affect the time required. However, factors such as development cost and time and the number of Shuttle flights required must be considered. Figure 7-9 illustrates the dimensional characteristics of the completed structure.

7.3 TECHNOLOGY DEVELOPMENT REQUIREMENTS - CANDIDATE SRT

A fundamental guideline for the MOSC vehicle definition was the maximum application of available hardware and technology to the flight subsystems.

Table 7-3

ASSEMBLY OF LARGE STRUCTURES IN SPACE

Task			Man-Minutes	
1		Set up work platform		720
	A.	Unstow and install work platform segments	(360)	
	B.	Unstow and set up assembly jig	(240)	
	C.	Unstow and check out tools and assembly aids	(120)	
2		Assembly reflector for each of 960 segments: 37.7 man-minutes x 960 elements =		36,150
	A.	Remove folded element from logistics pallet	(1.0)	
	B.	Place element in assembly jig	(1.0)	
	C.	Unfold and lock element in jug	(2.0)	
	D.	Install rigidizing members in element, 6 members	(12.0)	
	E.	Remove element from jig	(1.0)	
	F.	Transport the element to its attach point 233 ft/1 ft sec (Avg distance) = 233 sec - 7.8 man-min		
	G.	Install element, 4 fasteners	(6.0)	
	H.	Attach wire laminate over adjacent hole	(1.0)	
	I.	Relocate restraints and attachment aids to next attach location	(2.0)	
	J.	Locomote back to logistics pallet 233/2 ft sec = 116 sec = 3.9 man-min	(3.9)	
		Subtotal Items A through J	(37.7)	
3		Erect Mast and Feeder		2,400
	A.	Assemble feeder	(720)	
	B.	Deploy 120 ft tube and feeder	(60)	
	C.	Assemble 40 ft beam segments, 9 segments	(540)	
	D.	Assemble 120 ft tower	(720)	
	E.	Detach tube from pallet and slide base to apex of tower	(240)	
	F.	Rigidize tube to tower	(60)	
	F.	Align mast at tower/pallet interface	(60)	
4		Deploy Support Equipment		500
	A.	Relocate attitude control units from docking adapter to reflector	(300)	
	B.	Erect solar power panels	(200)	
		Total		39,770 = 662.8 manhours

662.8 manhours + 9.1% (662.8) rest periods = 723.1 manhours

$$\frac{723.1 \text{ manhours}}{9.6 \ \dfrac{\text{manhours}}{\text{MISSION DAY}}} = 75 \text{ mission days}$$

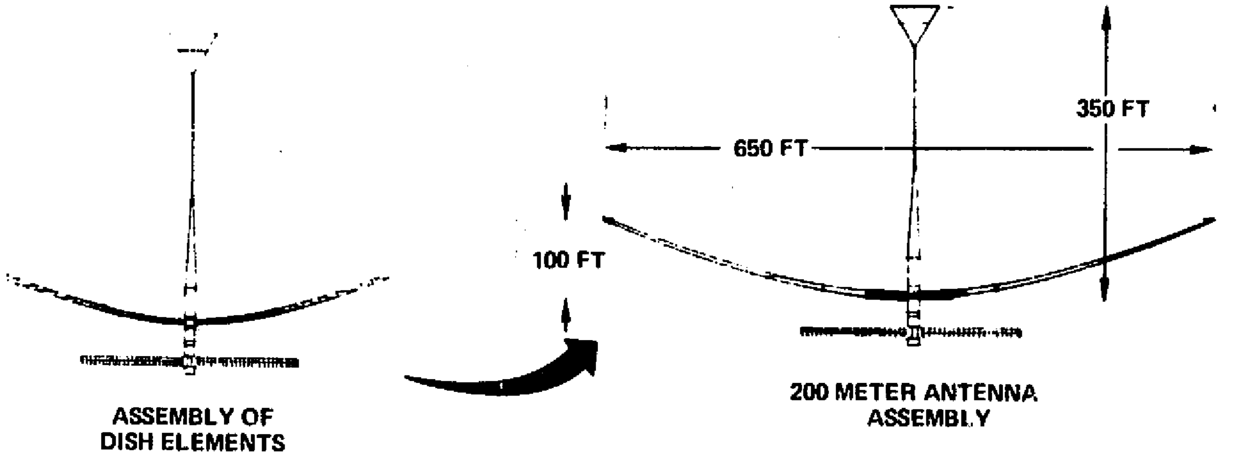

Figure 7-9. 200-Meter Antenna Assembly Sequence

This approach was one of the major elements of the minimum cost program structure because it significantly reduced the DDT&E costs. The successful execution of this guideline was possible because of the current spectrum of manned space-flight hardware development on the Space Shuttle and Spacelab programs and the Apollo and Skylab technology heritage. However, it was necessary in selected situations to utilize improved versions of existing hardware or components which are currently in development. These cases occurred in those subsystems which required increased performance or reduced weight or volume in order to meet a MOSC performance goal.

1. <u>Baseline Hardware Technology Development Requirements</u>
   The following hardware components/assemblies are integral members of the baseline subsystems and were selected on the basis of MOSC performance requirements and their development status. In each case there was a finite and desirable contribution in one or more of these areas: cost, weight, volume, electric power and/or long-life maintainability.

a. Water Reclamation - the vapor compression process (under development as advanced technology)

b. Electrical Power Source - lightweight solar arrays (under development for the SEPS program)

c. Stabilization and Control - increased capacity CMGs based on the Skylab hardware (was under development in 1972 as advanced technology)

In addition to this category, the second category includes growth candidates and items requiring additional study to ascertain the development needs.

2. Improvement/Growth Hardware Technology

The following items are candidates for further evaluation:

a. Structural/Mechanical - lightweight, large hatch opening docking assembly

b. Crew Accommodations -
   - automatic washing machine/dryer to save fixed vehicle weight by reducing crew stowage requirements
   - trash compactor which also sterilizes waste material subject to bacteria growth

c. Environmental Control and Life Support - mol sieve with pump-down water save system

d. Electrical Power -
   - improved efficiency arsenide gallium solar cells applied to space solar arrays
   - supplemental peak power with 2 to 5 Kw capacity
   - longer life batteries

e. Environmental Protection - more detailed definition of external contamination sources and protection requirements

The span of SRT ranges far beyond these candidates and it will be expanded and refined as the vehicle concept and requirements are further defined in subsequent studies.

APPENDIX A

MOSC DESIGN AND OPERATIONS SAFETY CRITERIA AND REQUIREMENTS

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Appendix A

MOSC DESIGN AND OPERATIONS SAFETY CRITERIA AND REQUIREMENTS

In the early examination of new mission concepts such as MOSC, safety awareness and considerations perform a very necessary function in alerting the designer to preventative design features that can be readily incorporated and can eliminate or control potential hazards in future flight operations. Accordingly, guidelines were established in conjunction with MSFC. They are described later in this appendix.

As described on the following pages, the safety criteria and requirements used in the MOSC Study were documented in two sections. Section A-1 is a draft of a NASA safety document entitled "Safety Policies and Requirements for Payloads using the National Space and Transportation System - October 1974." This document is a NASA Headquarters Level I document that will eventually be signed off by the Associate Administrator for Manned Space Flight. It is planned that each of the STS element program officers will utilize this document for all STS-related studies and programs. This document is therefore the highest-level safety document applicable to MOSC and was used in the MOSC study.

Section A-2 "MOSC Design and Operations Safety Criteria and Requirements - December 13, 1974" provides additional depth of safety criteria and requirements specifically applicable to manned systems as developed for the MOSC Study. This material was derived from the "Space Station Program (Modular) Safety Plan and Criteria" prepared under MDAC Contract NAS8-25140 with the Marshall Space Flight Center. This latter material was modified and updated to reflect the specific requirements of the MOSC Study and then approved for use by the NASA Study Manager.

The material appearing in Appendices A-1 and A-2 was used on all concept development and subsystem definition work and served as a basis for safety comparison between concepts, detailed design, and operations.

The task flow following in the analysis and evaluation of the MOSC configurations is shown in Table A-1.

Table A-1

CREW SAFETY ASSESSMENT TASK FLOW

- Establish Safety Guidelines
- Determine functional allocations of activities to modules
- Establish the energy sources that can produce potential hazards to conceptual configurations
- Identify experiments, systems, and mission power sources that have potential for generating hazards
- Define potential for hazards in the conceptual configurations prior to detailed design (guide to development of designs that minimize hazards to the program functions)

Once the safety guidelines were established, the next step was to determine the mission functional activities and their allocation to the various modules that will be used in defining the conceptual configurations. These functional allocations are summarized in Table A-2. These functions involved the incorporation of certain subsystems with their attendant potential hazard sources, which influence their location in the vehicle and the resulting interface design. The proper support of the crew in a free-flying vehicle such as MOSC requires a number of functions dedicated solely to crew support and safety, including emergency provisions and hazard retreat areas.

Table A-2

MOSC MODULE FUNCTIONAL ALLOCATIONS

Function	Module: Habitability	Subsystems	Logistics	Payload Module/Pallet
Crew Support				
Eat	Prime	—	Retreat	Retreat
Sleep	Prime	—	Retreat	Retreat
Hygiene	—	Prime	Retreat	Retreat
Atmosphere Storage	—	External	External	—
EC/LS	Atmos. loop	Controls	Atmos. loop	Atmos. loop
EVA/IVA	Airlock	—	Backup	Backup
Operational Support				
Thermal Service	Loop Radiator	Loop Radiator	Loop	Loop
Docking System	Module/ Orbiter	Module/ Orbiter	Module/ Orbiter	Module/ Orbiter
Elec Power Primary	Distr loop	Controls Solar panels	Distr loop	Distr loop
Emergency	Batteries	Batteries	Batteries	Batteries
G&N Stab. & Control	—	Controls Sensors	—	—
Propulsion System	Thrustors	Propellant	Thrustors	—
Space & Ground Data & Comm Link	Antennas Comm.	System	Comm.	Comm.
Control Panel	Payloads (prime)	Subsystems (prime)	—	—
Data	Store	Space ground link	Store (film, records)	Relay
Propellant	—	In systems	Tanks	—
Spares	Limited	Limited	Prime	Limited

In the third step of the assessment, potential hazards related to energy sources were listed as shown in Table A-3. The type of hazard was generalized including the damage or failure mode.

The fourth step in the assessment involved surveying the payloads support subsystems, and power sources that have a potential for generating hazards. These determinations are shown in Table A-4 for the reference MOSC payloads. The potential experiment hazards have been identified based on the installation concepts, power subsystems, mechanical features, and chemical components. The potential hazards for the basic modules and support subsystems are also shown, relative to the previously determined functional allocations to each module.

The basic nature of certain experiments (e. g., high voltages, lasers, high-energy radio frequencies, toxic gases and cryogens) creates hazards that can be minimized, but not eliminated, by thorough design. This includes isolation of the hazard outside of the manned modules and/or scheduling of hazardous operations on a safety priority basis. Cryogenic and high-pressure systems are required in a high-performance design and would become prohibitively heavy or large if low pressures and ambient temperatures were used. State-of-the-art design solutions exist that permit safe design for these hazard sources.

Finally, these various hazard potentials were examined with reference to the original safety guidelines, and a summary of safety guidelines was prepared for use in the design activity that will detail the configuration concept. This summary, shown in Table A-5 is based on the details contained in the safety guidelines (Sections A-1 and A-2) approved by MSFC. The grouping is by safety function to show the expected effect of the design considerations. The same degree of attention to safety features and design detail on all configuration concepts assured compliance with the safety hazard guidelines. Thus, safety as an evaluation factor on the different MOSC configurations did not differ

Table A-3

POTENTIAL HAZARDS IDENTIFIED IN CONCEPTUAL EVALUATION

ENERGY SOURCE	Type of Hazard	Damage or Failure Mode	Potential MOSC Involvement	Hazard Control Solutions Example
ELECTRICAL OR ELECTRO-MAGNETIC	Insulation Breakdown	Arcing/Shock Fire	All Modules & Shuttle	Design, Isolation, Shields
	Infrared RF	Burn	Experiments	Controls, Shields
	RF Exposure	Burn	Experiments	Controls, Shields
	Radiation	Radiation Effects	Experiments + Space	Shields
MECHANICAL	Pressure Vessels	Rupture	All Modules	Design & Tests, Pressure Relief
	Structural Strength	Distortion or Separation	All Modules	Design and Test
	Deployables	Distortion, Jam, or Separation	Systems Modules, Experiments	Design and Test, Control
	Momentum Storage Devices	Rupture	Subsystems Module, Experiments	Design and Test, Control
	Manipulation	Impacts, Interference	All Modules	Design and Test, Guides, Bumpers, Control, Training
CHEMICAL	Corrosive Fluids	Materials Change, Toxic	Resources Module, Experiments	Design, Isolation
	Flammable Materials	Heat, Smoke	All Modules	Materials Selection, Design, Isolation
	Ordnance Devices	Inadvertent Activation	TBD	
	Cryogens	Rupture, Fire	Resources Module, Experiments	Design, Isolation
	Contaminants	Toxic	All Modules	Materials Selected, Material Control & Rubbers
NUCLEAR	RTG's	Heat, Radiation	No	Coolant, Isolation, Shielding
OPERATIONS/ PROCEDURES	Crew Retreat	Atmosphere Unusable	Two Pressure Volumes	Two or More Pressure Volumes Connected
	Crew Escape	Station Uninhabitable	Rescue Orbiter	Emergency Retreat/ Supplies

Table A-4
POTENTIAL HAZARD SOURCES

Energy Sources		Electro/ Electromagnetic										Chemical					
Mission		Hazard Types															
Payload Group	SSPDA* No.	High Voltage	Laser	High RF	Radiation Source	High Magnetic Fields	High Pressure	Mechanisms	Pyros-Ordnance	Bio Specimens	High Temperature	Toxic Gas	LO_2	LN_2	LH_2	LHe	Remarks
C-01	AS-01-S AS-15-S	X					X	X			X	X			X	X	
C-02	AS-03 AS-04 AS-08-S AS-10-S	X					X	X				X			X	X	
C-03	AS-13-S SO-01-S						X							X			
C-04	AS-06-S CN-02-S	X	X	X			X	X	X						X		Shaped chargcs gas
C-05	AS-06-S CN-04-S CN-06-S	X	X	X			X	X	X						X		Shaped charges gas
C-06	AP-06-S EO-07-S OP-0S-S	X	X	X			X	X	X						X		Shaped charges gas
C-07	SP-14-S ST-04-S ST-05-S	X	X				X			X	X		X		X		
C-08	EO-01-S ST-21-S ST-22-S	X	X	X			X	X		X	X			X			
C-09	EO-05-S OP-02-S OP-00-S	X	X	X													
C-10	EO-05 EO-06-S OP-03-S OP-04-S	X		X					X								
C-11	AS-19-S HE-14-S HE-19-S ST-06-S						X				X						
C-12	LS-07-S LS-10-S SP-09-S SP-05-S SP-16-S	X	X	X			X	X		X	X	X					
C-13	LS-09-S LS-10-S SP-15-S SP-19-S	X	X	X			X			X		X					
C-14	AS-31-S						X										
C-15	AS-54-S						X										
C-16	HE-X-S	X				X	X										
C-17	LS-X-S				X		X			X		X					
C-18	ST-23-S	X	X	X				X									
C-19		X								X	X						
STATION SYSTEMS	Habitation module							X		X		X					Eat, sleep, command
	Subsystems module	X		X			X	X				X	X	X			Systems, hygiene
	Logistics module	X					X	X				X	X	X			Consumables
	Payload module/pallet	X						X		X		X					
	Docking adaptor							X									

*Space Shuttle Payload Description Activity

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Table A-5

SAFETY FEATURES TO BE INCORPORATED IN DETAILED PRELIMINARY DESIGN

Redundancy

X Divide into pressurized compartments.
Communications with EVA crewman.
Control of propulsion firing.
Fail operational anomaly signals to crew.
X Redundant systems located apart.
X Independent emergency thrustors for docking.
Redundant restraining system for docking mechanisms
X Multiple docking ports.
X Emergency communications system independent from normal intercom.
X Emergency lighting in compartments independent from prime power source.
X Emergency oxygen masks and individual oxygen supplies
X EVA PLSS independent of EC/LS.
Warning system redundancy.
Hatch pressure seals
Manual override for all automatic life essential and mission-survival functions.

Emergency

Warning systems/indicator.
Critical functions – fail operational.
X Fire detection and suppression.
Rapid evacuation of personnel from payload bay
X Personnel escape routes
X Provisions for damage control and repair.
X Current protection devices.
Detection, location, repair meteoroid damage.
X Rapid repressurization of one module.
X Atmosphere consistency monitor and control.
Water potability monitor and control.
X Rescue provisions for EVA/IVA.

Isolation

Incompatible materials.
Radioactive materials.
Flamable materials.
X Control of loading or installation of ordnance components, high-pressure devices and hypergolics.
Separation of redundant hardware.
Safe disposal of expended hardware.
X Single damaged pressurized compartment.
Biological specimens.
Specimen cages pressure, supply/discharge.
X High-pressure vessels and volatile gas or propellant tanks outside of crew spaces.
Toxic materials packaged and sealed.
X Isolate contaminated atmosphere from orbiter and from man retreat volume.
X Isolate emergency situation.
Selective fan cutoff and air duct closure.
EVA isolated from:
Artificial g operations.
X Docking.
X Movement of logistics modules or payload modules.
Attitude/rate corrections.

Materials Selection

Minimum flammability and outgassing.
Nontoxic heat transport fluids in man space.

(X) These safety items were evaluated at the conceptual level and included in the MOSC configurations.

significantly from one concept to another, and to work within the prescribed guidelines, safety was introduced into the evaluation of all configurations and operations. This resulted in a recommended conceptual design that will function within (1) acceptable identified risks, and (2) excluded risks. The successful end result is based on application of safety criteria, requirements, and previous experience.

To provide an appreciation of a typical experiment program and the number of hazards that must be safety controlled, a hazard frequency summary is shown in Table A-6. This includes the total of the hazard categories shown in Table A-4.

Table A-6
FREQUENCY OF HAZARD POTENTIAL

Energy Source	Hazard		Payload Groups (19 Total)	Modules (Total)
Electro/ electromagnetic	High voltages		14	3
	Laser		9	-
	High RF		9	1
	Radiation source		1	-
	High magnetic fields		1	-
Mechanical	High pressures		15	2
	Mechanisms		8	5
Chemical	Pyros-ordnance		4	-
	Bio-specimens		6	1
	High temperature		6	-
	Toxic gas		5	1
	Cryogens	LO_2	1	2
		LN_2	6	2
		LH_2	6	-
		LHe	2	-

Many of the payload groups were found to have high voltages and high-pressure systems that can be managed as controlled hazards by locating the source away from manned operations and employing proven leak-before-burst bottles. In some cases, by activating the source when the other operations cause minimum interference will create the least risk. In general, it can be concluded that in any particular mission there will be a number of potential hazards from the payload equipment which must and can be isolated and/or safely controlled through early design analysis.

The thrust of these conceptual safety considerations is to provide guidance for a more detailed analysis during subsequent studies, including preliminary and detailed design, detailed operational analysis, and detailed crew timelines.

The following set of first-tier configuration-level safety criteria are those which were universally applied to each MOSC configuration:

- Subsystem failures — fail-operation — fail-safe with an emergency subsystem available to permit normal rescue operations.* This protects the mission against a single failure (fail operational) and the crew against a double failure (fail safe) and provides the crew with emergency provisions. The structural shell, secondary structure, and hard fluid lines were accepted as an absolute requirement. Detail subsystem designs can in many cases provide a degree of inherent redundancy (e.g., separating gas storage bottles into two banks with independent redundant valving).
- Module isolation — in the event of failure at least one escape route will be available from all modules to an isolatable pressurized module containing emergency supplies for the crewmen during a normal shuttle rescue operation.
- Docking ports — two docking ports will be available for use in normal or emergency operations. The docking ports will be located on modules with emergency support subsystems. In the pallet operations mode, if the docking assembly was not operable, then (1) the pallet(s) would have to be disengaged and either jettisoned or stowed in the Shuttle Orbiter bay, or (2) the crew would have to transfer to the Shuttle Orbiter by EVA.

*Current planning indicates a 160-hour shuttle turnaround under emergency conditions.

- Airlocks -- two airlocks or equivalent will be available for use in normal or emergency operations. They will be located in modules containing emergency supplies.
- EVA equipment -- pressure suits and personal rescue systems (PRS) will be stored in each airlock in sufficient numbers to support EVA from either of the two airlocks by the entire crew.
- Emergency supplies -- sufficient supplies to support the crew during rescue operations will be stored in modules with Shuttle docking capability at each end of the MOSC. The supplies will be contained in a pallet which can be moved to other modules. The pallet will contain all consumables (i.e., water, food, GN_2 and GO_2). It will contain a lithium hydroxide canister for CO_2 and humidity control. The necessary control subsystems will be an integral part of the pallet. Emergency electrical power and communications subsystems will be independent of the pallet.

Although safety requirements ultimately must be imposed on all elements of operational procedures and hardware design, the MOSC study concentrated on the safety features associated with crew rescue, assuming a hazard or catastrophe disables one of the modules. Figure A-1 shows the general inboard profile of the MOSC 4-man Baseline vehicle relative to the crew safety equipment and conceptual design features.

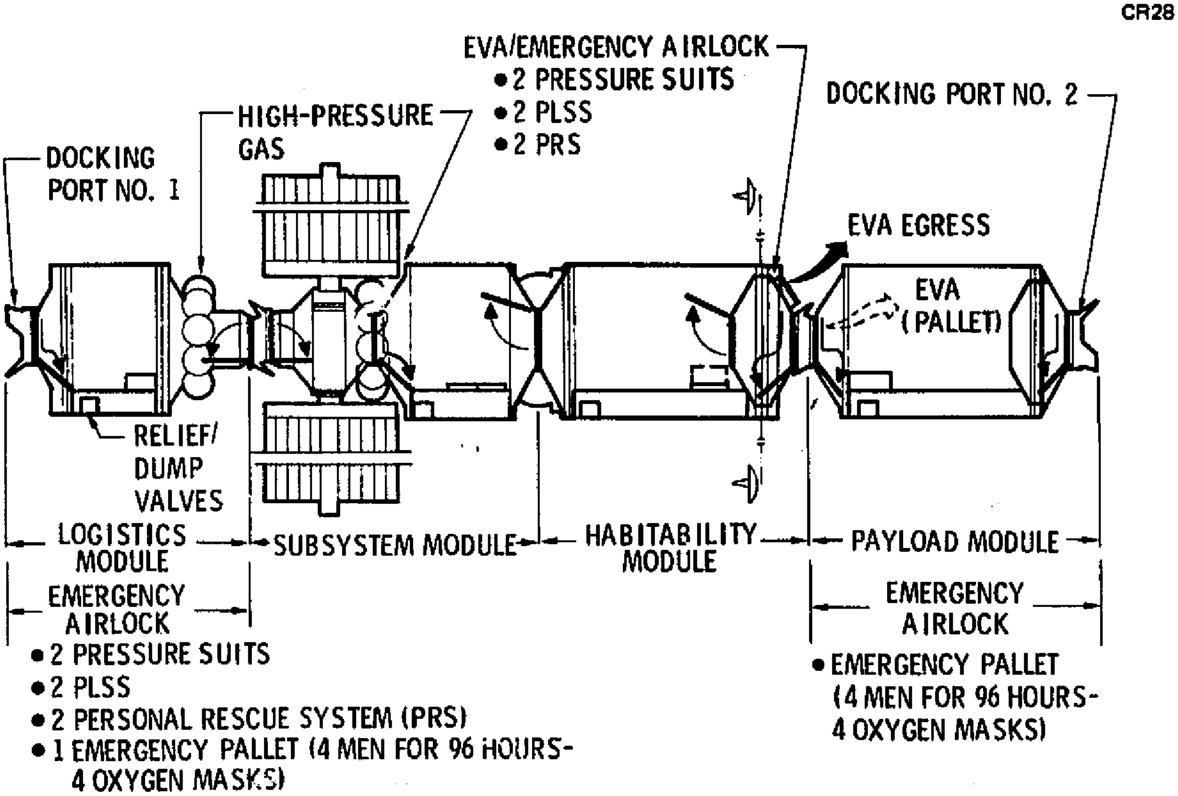

Figure A-1. Baseline 4-Man MOSC Safety Equipment Summary/Locations

Section A-1

SAFETY POLICY AND REQUIREMENTS FOR PAYLOADS USING THE NATIONAL SPACE TRANSPORTATION SYSTEM

Payload Safety Steering Group
NASA Headquarters, Code MQ
July 1974 (Revised October 1974)

NOTE: Only those portions directly applicable to the MOSC Study are included for reference.

PREFACE

The Space Transportation System (STS) consists of the Space Shuttle, Spacelab and Upper Stages (Space Tug and Interim Upper Stage). This system will be used to deliver, support and/or return payloads to and from low Earth orbit, geosynchronous orbit and planetary missions.

It is a basic policy on the STS that before payloads can be accepted for flight, it is necessary to perform the minimum but sufficient safety assessments to demonstrate that the payload is safe to carry through all phases of the mission (from pre-launch ground checkout through landing and payload removal).

The STS itself will contain basic safety capabilities inherent in its design. In addition, it will have dedicated safety equipment to insure the safety of the Orbiter and flight personnel. Examples of safety capabilities and equipments are shown below but users should review the appropriate Accommodation Document for complete listings.

a. Intact abort capability.
b. Caution and warning subsystem.
c. Command override provisions.
d. Vent provisions.
e. Transmittal of crew alerts from ground voice transmission.
f. Portable fire extinguishers.
g. Necessary controls to prevent collision with payloads during rendezvous and docking/berthing operations.
h. Radiation measurement devices to measure dose rate and cumulative dose to flight personnel.
i. A ground-supplied, dry nitrogen inerting purge of the Payload Bay after Orbiter Payload Bay door closure to reduce the oxygen content to a safe level until launch umbilical disconnect.

j. Portable oxygen supply of 10-minute duration.
k. Standard interface for STS users.
l. Safe-haven feature of the Orbiter cabin.
m. Dump provision for liquid-propulsive upper stages.
n. Atmospheric contaminant detection sensors.

In general, all payloads will be carried in the 15 X 60 foot Orbiter Payload Bay. Payload support equipment (PSE) may be installed either in the Orbiter cabin or in the Payload Bay. Some unique payloads such as biomedical may, by their nature, be carried in the Orbiter cabin. Wherever installed, PSE and payload GSE, which is temporarily taken on board, are subject to the same STS requirements regarding safety.

It is the responsibility of those involved in payload development to assure the safety of the hardware which they propose to install in the STS. It shall be the responsibility of the operators of the STS to review the payloads from the safety standpoint and to assure that they impose no undue hazards to the total flight systems.

Clearly it is advantageous in most instances to have early STS Safety personnel participation in payload design. This is available on a continuing basis through the Safety organization located in each of the NASA centers. A handbook will be developed describing basic hazard concerns in detail and to explain the rationale behind the various requirements. This handbook will also include optional guidelines for safe design, handling and operation. This information should be particularly useful to those new to space flight. Checklists will also be available to facilitate communications between STS user and the safety organization. Appendix A lists a Glossary of Terms.

Questions concerning the intent of the provisions herein should be referred to the Director, Reliability, Quality and Safety, Office of Manned Space Flight, Washington, D.C. 20546.

2.2 Hazard Classification Levels: A hazard whereby environment, personnel error, design characteristics, procedural and operational deficiencies or subsystem malfunction may result in loss of personnel capability or loss of system shall be categorized as follows:

a. Uncontrolled

(1) Catastrophic — No time or means are available for corrective action and the hazard may lead to loss of personnel; loss of major elements of the STS or its cargo or ground facilities or to injury of the public or ecology.

(2) Critical — May be counteracted by emergency action performed in a timely manner but, if not counteracted, could lead to serious injury of personnel, the public and/or environment or major STS elements or its cargo or ground facilities or other payloads.

b. Controlled — Has been counteracted by appropriate design, safety devices, alarm/caution and warning devices or special automatic or manual procedures.

2.3 Hazard Reduction Precedence Sequence: To eliminate or control hazards, the payload supplier shall use as a minimum the following sequence or combination of items:

a. Design for Minimum Hazard — The major goal throughout the design phase shall be to insure inherent safety through the selection of appropriate design features. Damage control, containment and isolation of potential hazards shall be included in design considerations.

b. Safety Devices — Hazards which cannot be eliminated through design selection shall be reduced through the use of safety devices as part of the system, subsystem or equipment.

c. Warning Devices — Where it is not possible to preclude the existence or occurrence of a known hazard, devices shall be employed for the timely detection of the condition and the generation of an adequate warning signal. Warning signals and their application shall be designed to minimize the probability of wrong signals or of improper personnel reaction to the signal.

d. Special Procedures — Where it is not possible to reduce the magnitude of an existing or potential hazard through design or the use of safety and warning devices, special procedures shall be developed to counter hazardous conditions for enhancement of ground and flight crew safety.

e. <u>Residual Risks</u> — Hazards which remain after application of the hazard reduction precedence sequence are residual risks. These shall be identified and the rationale for acceptance avoided.

2.4 <u>Hazard Control Evaluation Summary</u>: A summary of corrective actions taken to control/eliminate all identified hazards shall be performed and documented. Each final decision should be supported by a rationale.

2.5 <u>Safety Assessment Reviews:</u> Safety reviews shall be conducted to assess the compliance of each payload element to the above safety requirements.

These reviews will be accomplished progressively on individual experiments or payload elements prior to acceptance by and shipment to an experiment package integrator or spacecraft integrator and again on the integrated packages or complete spacecraft prior to acceptance and shipment to the launch area for integration with the transportation system. In each case, the "next assembly" level organization will be responsible for reviewing and accepting the safety assessments for hardware (and its operation) for which it is responsible. Each level of organization will present a Certificate of Compliance of its equipment with the above safety requirements. This will in turn be endorsed by the "next assembly" level organization and will culminate in a final safety review prior to flight. It is intended that the responsibility for "presenting" the safety compliance moves up the ladder in the same way that the "next assembly" organization is moving up. These reviews will be conducted as part of the overall milestone design and readiness reviews.

Appropriate documentation associated with the safety assessments at each prior level will be made available to each "next assembly" level and for the final safety review prior to flight, sufficiently in advance to allow adequate review prior to the Safety Assessment Meeting. In cases where and software are used for multiple flights, the assessments need only cover a delta which would include any hardware or software changes and/or refurbishment effected since a previous flight. (See paragraph 4.17.).

2.6 Safety Compliance Data Package: At the time of a safety review the payload supplier shall submit a data package consisting of the following:

a. Hazard summary consisting of:

   (1) Residual hazards and rationale for acceptance. (See paragraph 2.3e.)

   (2) Hazard classification level. (See paragraph 2.2.)

   (3) Hazard control action with analysis/evaluation. (See paragraphs 2.3 and 2.4.)

   (4) Source of hazard identification (e.g., stress analysis, sneak circuit analysis, tests, etc.).

b. Waivers to safety requirements. (See paragraph 5.0.)

c. A listing of identification and quantities of hazardous materials in each payload including those which are toxic (under the conditions in which they will be exposed to personnel), flammable and explosive. (See paragraph 4.5.)

d. A listing of radioactive materials and equipment generating hazardous radiation.

e. Assessment of failures or accidents related to payload test, checkout or operations that could have an impact on STS safety.

f. Data requirements per paragraph 4.17 for flights of reusable payloads which are being reflown.

g. An overall certificate of compliance signed by the payload manager.

h. Test result summaries showing successful completion of testing for safety requirements to be verified by test.

i. Analysis summaries for those safety requirements verified by analysis. These analyses will be approved by the payload manager.

j. Procedures covering those hazards to be controlled through procedure.

k. Inspection certificates covering those safety requirements to be verified by inspection.

3.0 ACCIDENT/INCIDENT/MISSION FAILURE INVESTIGATION AND REPORTING. Accident/incident/mission failure investigation and reporting for NASA equipment will be handled under the provisions of NPD 8621.1A and

NHB 1700.1 (VI). Accidents/incidents/mission failures occurring after delivery to NASA facilities, investigation and reporting will be in compliance with NASA regulations.

4.0 DESIGN AND OPERATIONAL REQUIREMENTS. The following items represent policy which is conducive to maximizing safety. These requirements do not specify design solutions in order to provide maximum flexibility to the designer. They do represent STS safety requirements which shall be followed throughout the program.

4.1 Protective devices or provisions against payload-generated hazards shall be provided for STS safety at all times while the payload is near to or installed in any element of the STS. (In view of Shuttle's abort capability, expendable payloads are subject to this requirement through Orbiter landing and post-landing operations.)

4.2 A safe interface between the STS elements and payloads shall be maintained under nominal, contingency and emergency operations of either the STS or its payload. The safety of the interface during attached and/or detached operations shall be designed failsafe. At least two procedural operations shall be required for initiation of safety-critical functions. A hazard shall not result from any single procedural error.

4.3 The capability shall be provided for redundant transmittal to the Orbiter Caution and Warning System that payload data which is critical to the safety of the STS or its flight personnel. The redundancy may be accomplished via hardwires and/or via the Orbiter PMF (Performance Monitoring Function), and it includes redundant sensors. The parameters to be transmitted and monitored will be mutually determined with the user. Appropriate controls for safing the payload shall be provided.

4.4 Payload safety-critical data and control functions shall be capable of being tested for proper functioning from the Orbiter and from the Spacelab where applicable.

4.5 All materials in the payload, PSE and interfacing GSE which may effect STS safety shall conform to the "intent" of NASA Level I Flammability and Offgassing Requirements of NHB 8060.1A (entitled "Flammability, Odor and Offgassing Requirements and Test Procedures for Materials and Environments that Support Combustion"). (Guidelines for meeting this "intent" are under preparation and will be supplied as a supplement to this document.)

4.6 Safety-critical subsystems or components of payloads shall withstand the STS environments and shall be designed for minimum hazards if improperly employed/deployed or accidentally damaged.

4.7 Payloads requiring the presence of man in the Payload Bay shall not preclude rapid evacuation of personnel from the Payload Bay in the event of an emergency.

4.8 Hazardous materials, fluids and gases shall not be released or ejected into the Payload Bay from payloads. Venting, relief and release of material from payloads shall be designed to use the Orbiter-provided vent system. Control of the venting by the Orbiter for certain mission phases may be required. Relief of inert gases under some conditions may be permitted. A capability shall be provided for dumping liquid propellants of propulsion stages and relief of pressurants overboard through the Orbiter dump and vent systems. This shall be accomplished within the time constraints imposed by abort and shall be applicable with the payload doors open or closed.

4.9 Redundant equipments shall be separated to prevent hazard propagation.

4.10. The payload shall be designed or protection provided to preclude hazards to the flight personnel under crash-landing loads.

4.11 Where hazards can occur due to the presence or contact of mutually incompatible materials, components at electrical potential or of chemically-incompatible substances, such components or substances shall be separated to the maximum practical extent.

4.12 The Standard Manned Space Flight Initiator, which meets reliability and safety requirements for the Space Shuttle or any initiator meeting the requirements of JSC 08060, "Space Shuttle System Pyrotechnic Specification," shall be used.

4.13 Payloads that contain radioactive materials or that contain equipment that generates ionizing radiation shall be identified and approval must be obtained for their use. The initial description shall state source type, strength/quantity, containment/shielding, and chemical/physical form. Review will be implemented through the NASA center responsible for development of the payload. In the event that a NASA center is not involved in the development, review will be implemented by the Safety Office of the STS operations organization. Major radioactive sources require approval by the Interagency Aerospace Nuclear Safety Review Panel through the NASA coordinator for the panel. DOD payloads involving radioactive materials will be processed through their coordinator on the review panel.

4.14 Flammable, odor-producing, outgassing and/or corrosive materials which may come in contact with the Orbiter cabin atmosphere shall be consistent with the Orbiter project requirements as defined in the Shuttle Payload Accommodation Document.

4.15 Pressure vessels shall be in accordance with NASA Aerospace Pressure Vessel Safety Standard NSS HP 1740.1 or in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Divisions 1 and 2.

4.16 Prior to installation of any payload equipment into the Orbiter, the equipment shall have been satisfactorily verified for the expected operational regimes. Analysis and/or test are two techniques for such verification.

4.17 Payloads which have flown on previous flights shall be verified for: (a) correction of any safety deficiency encountered on previous missions, (b) safety impact of any changes made to the hardware or operation procedures, (c) any maintenance and/or refurbishment affecting safety and (d) appropriate design features for reuse or reflying.

4.18 Safety procedures shall be demonstrated to meet the requirements herein and to have the desired effect in controlling hazards.

4.19 Payload design and operations shall not impose restrictions on normal or contingent Space Shuttle operations (including intact abort and rescue operations) in which the safety of the STS or flight personnel may be affected.

4.20 Contingency safety planning (emergency or back-out procedures) for ground or flight anomalies involving Shuttle payloads shall be developed.

4.21 Destruct systems shall not be used.

4.22 The mission will be terminated by abort during launch or by early mission termination after reaching orbit if a situation arises whereby a subsequent Space Shuttle or payload failure could result in personnel injury/death or damage to the STS.

4.23 All safety-critical command and control circuitry associated with engine firing, primary propulsion systems or auxiliary propulsion systems shall be designed to accept two failures without causing a hazard to the Space Shuttle system.

4.24 Payloads within the habitable environment shall not exceed Orbiter toxic contaminant levels. If an all up, complete assembly test is not performed, it shall be necessary for the payload user to establish that there are no toxological hazards. This may be done by analysis of materials, operational environment or offgassing tests. The toxological hazard assessment must be approved by the NASA Safety organization in the NASA group responsible for payload development. If there is none, then by the Safety Office of the STS operations organization.

5.0 <u>WAIVERS AND DEVIATIONS.</u> If a requirement cannot be fulfilled, a waiver is required identifying the requirements which cannot be met, the reasons why they cannot be met and the impact on safety which would result

from not meeting the requirement and the method/process for controlling the hazard. Waivers shall be submitted by the payload supplier and approved by the "next assembly" organization. Waivers are to be kept visible at the various payload assessment levels and shall receive approval of the final payload acceptance authority.

GLOSSARY OF TERMS

Accident/Incident – An unplanned event which results in personnel fatality or injury, damage to or loss of STS, environment, public property or private property or could result in an unsafe situation or operational mode. An accident refers to a major event whereas an incident is a minor event or episode that could lead to an accident.

Catastrophic Hazards – Those hazards that could cause loss of personnel or vehicle.

Caution – Notification of an impending unsafe condition. Corrective measures are required immediately.

Certificate of Compliance – A formal documented buy-off of the safety assessment effort.

Critical Functions – Functions required for personnel and vehicle safety.

Critical Hazards – Those hazards that may result from a hardware failure that could cause the return of one or more personnel to Earth, or could cause the loss of functions essential to continuing space operations and scientific investigations.

Emergency Level – A level of performance sufficient only for personnel survival.

EVA – Activities carried out by a suited crewman in a space environment and outside of the spacecraft.

Failsafe – The ability to sustain a failure without causing an accident/incident.

Flight Crew – Any personnel onboard the Space Shuttle engaged in flying the Space Shuttle and/or managing resources on board (e.g., Commander, Pilot, Mission Specialist).

Flight Personnel – All personnel carried on the Space Shuttle vehicle.

Free-flying Automated Spacecraft – A payload which is deployed and separated from the Orbiter.

Habitable Module – Any module in which a man may enter and perform activities in a shirt-sleeve environment.

Hazard Analysis – The determination of potential sources of danger and recommended resolutions in a timely manner for those conditions found in either the hardware/software systems, the man-machine relationship or man-environment relationship or combinations thereof which could cause loss of personal capability, damage to or loss of system or loss of life or injury to the public or to the environment.

Intact Abort – An abort of the mission wherein the crew, payload and the vehicle are returned to the launch site.

Interface – Any contact between two or more independently developed elements of the flight or ground systems including hardware, electrical connection, EMI, thermal radiation, man, etc.

IUS – An Interim Upper Stage to be available at Shuttle IOC. Same as "Tug" but with lesser capability (viz., payload deployment capability only).

Multiple Payloads – More than one separate payload carried in the Payload Bay.

Nominal Level – The level of performance or operations for which the system was designed.

Payload — Any equipment or material carried by the Space Shuttle in the Payload Bay or cabin that is not considered part of the basic Space Transportation System. It, therefore, includes items such as Free-flying Automated Spacecraft, individual experiments, PSE, etc.

Payload Safety-critical Data — That payload-originated data which is necessary for the safe, well-being of the STS.

PSE (Payload Support Equipment) — The flight equipment needed to support the payload such as caution and warning, data recording, controlled functions, instrumentation, etc.

Reduced Level — A level of performance lower than that for which the system or operation was designed, but still adequate for personnel safety.

Residual Hazards — Hazards which cannot be eliminated or controlled by automatic or manual backup operations and/or safety-monitoring provisions or other equipment.

Safety — Freedom from chance of injury or loss of personnel, equipment or property.

Safety-critical Hardware — That equipment which may affect the safety of the Space Shuttle flight personnel, the Space Shuttle flight personnel, the Space Shuttle system, the Orbiter, payload, the general public and public/private property.

Space Shuttle — Those elements of the Space Transportation System consisting of the Orbiter, the external tank and the solid rocket boosters.

Space Transportation System (STS) — The Space Shuttle vehicle including the Orbiter, the solid rocket booster, the external tank, flight personnel and "carriers" such as IUS, Tug and Spacelab.

Toxic Constituents – Those constituents that may be deleterious to the health or well-being of onboard personnel, or may degrade crew performance so as to affect mission performance, or may interfere with physiological functions in such a manner as to bias results of medical experiments.

Tug – An unmanned, high-energy, propulsive stage used to extend the operating regime of the Space Shuttle from low Earth orbit to geosynchronous orbit and beyond. It may consist of one or more individual stages and is carried into low Earth orbit by the Space Shuttle.

Warning – An indication that the safe limit has been exceeded and emergency procedures are to be initiated.

GOALS

No single malfunction shall result in loss of personnel or vehicle. Catastrophic and critical hazards shall be eliminated or controlled.

Section A-2
MOSC
DESIGN AND OPERATIONS SAFETY CRITERIA AND REQUIREMENTS

December 13, 1974

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MOSC DESIGN AND OPERATIONS SAFETY CRITERIA AND REQUIREMENTS

1.0 GUIDELINE AND CONSTRAINTS SAFETY REQUIREMENTS

The following guidelines and constraints safety requirements apply:

A. Safety is a mandatory consideration through the total program. The goals and requirements identified in Section A. 1 will be imposed as applicable.

B. Crew responsibilities will include safety, damage control, corrective action, and escape.

C. All components associated with enabling the crew to recognize, isolate, and correct critical system malfunctions for a given vehicle must be located onboard and be functionally independent of ground support and external interfaces.

D. Program hardware will be designed, and prelaunch and launch operations will be developed so as to require minimum access to the space vehicle while on the launch pad. Checkout personnel will egress prior to propellant loading.

E. Personnel escape routes will be considered in all situations of high hazard potential.

F. The loading or installation of ordnance components, high pressure devices, and hypergolics into the MOSC, and other associated activities that pose a safety hazard to ground personnel will be analyzed. Installation of hypergolics and ordnance-initiator devices in the vertical assembly building (VAB) is not permitted. Installation of other ordnance should be planned as late in the VAB processing flow as possible.

G. Ground access through docking ports will be provided for servicing, troubleshooting, and component replacement in, and escape from, all areas of the MOSC. Docking ports will be closed and sealed prior to transport of flight hardware to the launch pad. However, contingency access through these ports will be available on the pad.

H. Provisions for emergency returns from the MOSC will be provided by the Space Shuttle Transportation System (STS). This capability will be provided subject to availability of STS.

I. All materials selected for use in pressurizable areas of the MOSC will be nontoxic, nonflammable, and nonexplosive to the maximum extent possible over the entire range of possible atmospheric conditions.

J. Radiation protection for crew members will provide at least a 99 percent probability (at no less than a 90 percent confidence level) that radiation dose during extended occupancy will not exceed the following:

LIMIT DOSE (rem)*

Organ	Career/ 20 Years	Annual	Quarter	Month	One Yr. Avg. Daily Rate
Skin	1200	225	105	75	0.6
Eye	600	112	52	37	0.3
Testes	200	38	18	13	0.1
Marrow	400	75	35	25	0.2

Limiting doses applicable to occupancy periods of less than 2 years may be twice the annual limits above, provided no exposure is received during the remainder of the 2 year period and that the quarterly and monthly limits are not exceeded. For example, 75 rem may be received by the marrow during a 6 month mission provided no further exposure occurs during the ensuing 18 months.

K. Systems design and operational planning will provide for the safe disposal of obsolete and expended program element hardware (e.g., spend launch vehicle stages, experiment modules, nuclear power sources, laboratory or operational hardware).

L. The atmosphere within the MOSC pressurized modules will be conserved whenever practical when a planned depressurization occurs (e.g., airlocks, hangars, etc.). Gases dumped overboard will utilize nonpropulsive discharge systems.

M. Carbon dioxide tensions (partial pressure) on the MOSC will be maintained below 3.0 mm Hg in all habitable areas.

*Per instructions to ERNO for Spacelab.

N. MOSC structure, design and arrangement will provide access for damage control and repair.

O. All systems that incorporate automated fail/operational capability will be designed to provide crew notification and data management system cognizance of component malfunction until the anomaly has been corrected.

P. Redundant paths, such as fluid lines, electrical wiring, connectors, and explosive trains, shall be located to ensure that an event that damages one line is not likely to damage the other.

Q. Microbiologically and bacteriologically contaminated waste material will be disinfected as close as possible to its source prior to storage, processing, or disposal. The concentration of bacteria in the atmosphere within each of the pressurized compartments containing crew quarters, process laboratories or experimental facilities will be monitored and controlled.

R. The commander's compartment should be located in the same pressure compartment as the primary command and control center.

S. It is desirable that the MOSC be divided into pressurized compartments, as required, that any single compartment can be isolated in case it is damaged or rendered untenable. The remaining compartments will be equipped and provisioned so that the crew, in safety, can continue a degraded mission in the remaining compartment; take corrective action to restore the untenable compartment; or return to Earth.

T. The MOSC structure will be designed in accordance with conservative design factors (e.g., a factor of two times design loads on primary structure).

U. The MOSC structural design will provide for a probability of 0.9 for no meteoroid penetration of crew or systems compartments for the planned life of the facility. (NOTE: This probability will be refined as a function of detail design.)

V. The MOSC will use ground power until the final portion of countdown and will provide the capability for switchover to internal power without degradation of vehicle performance or compromising safety.

W. The electrical system will provide circuit protection devices for all MOSC distribution wiring, where necessary.

X. The capability will be provided for monitoring the MOSC when unmanned to confirm the existence of a habitable environment and the functional capabilities of critical life-sustaining subsystems prior to committing to the launch of a crew.

Y. A capability for redundant communications with EVA crewmen will be provided.

Z. Consideration will be given for detecting, locating and repairing meteroid damage.

AA. The MOSC structures and subsystems will be designed for an oxygen/nitrogen mixture at a normal operating pressure of 14.7 psia.

AB. The MOSC life support and environment control subsystems will be designed to remove carbon dioxide (CO_2) from the atmosphere.

AC. Atmospheric stores and subsystem production capability sufficient for rapid repressurization of at least one pressurized module will be maintained on the MOSC at all times.

AD. The atmosphere constituents, including harmful airborne trace contaminants, will be monitored and controlled in each pressurized compartment of the MOSC. Provisions for odor control within each pressurized compartment of the MOSC will be provided.

AE. Prior to use on the MOSC, the potability of resupply water must be verified. The potability of water used by crewmen will be monitored and controlled.

AF. Heat transport fluids located within pressurized crew compartments should be nontoxic and nonflammable at ambient atmosphere pressure and composition.

AG. Emergency rescue provisions for crewmen performing EVA and IVA events will be provided.

AH. Use of one-gas (oxygen) pressure suits may require preconditioning of the crewmen. Facilities for prebreathing 100-percent oxygen will be provided should EVA activities dictate this procedure to preclude dysbarism.

AI. Crewmen will use portable life support to perform EVA.

AJ. Automated critical DMS control functions will have a manual or self-check override/interrupt capability, or both.

1.1 Guidelines and Constraints Document

The following material concerning safety is quoted directly from Guidelines and Constraints Document, Appendix "A" of the MOSC Statement of Work.

"Capability shall be provided for performing critical functions at a nominal level with any single component failed, or with any portion of a subsystem inactive for maintenance.

"Capability shall be provided for performing critical functions at a reduced level with any credible combination of two component failures, or with any credible combination of a portion of a subsystem inactive for maintenance and failure of a component in the remaining system.

"Capability shall be provided for performing critical functions at an emergency level until the affected function can be restored or the crew returned to earth—A. With any one compartment inactivated, isolated and vacated due to an accident, or B. As a result of an accident and a portion of a redundant or backup system inoperative.

"For those malfunctions and/or hazards which may result in time-critical emergencies, provision shall be made for the automatic switching to a safe mode or operation and for caution and warning of personnel.

"The chemical composition of the environmental atmosphere shall be continuously monitored for any buildup of toxic and/or noxious gases, as well as provide early fire hazard warning by detection of fire precursors or materials decomposition products.

"An integrated and comprehensive fire detection system shall be provided in order to detect incipient fires in components, behind panels, and in wire bundles or cabling assemblies. Flame monitoring devices also shall be considered.

"The fire suppression system shall be capable of extinguishing any fire in the most severe oxidizing environment prior to failure of primary pressure structural materials, both automatic general area extinguishing systems and manual portable.

"All materials shall be noncombustible or self extinguishing before half of the sample is consumed when exposed to an open flame in the most severe oxidizing environment to which they will be exposed.

"In those instances where functional requirements preclude meetings these flammability requirements, such materials shall be isolated from the environment by fireproof storage compartments or barrier materials which meet these requirements.

"Materials shall not offgas or evolve either toxic or noxious products which may either present a personnel hazard or impairment of its primary function over the anticipated mission duration."

2.0 GROUND OPERATIONS SAFETY REQUIREMENTS

The following safety requirements for ground operations will apply:

A. Any equipment carried onboard during ground operations (flight hardware, loose experiment equipment, flight spares, cargo packages, GSE, etc) will fit within an envelope (undetermined in detail since it depends on specific MOSC and Ground Support Equipment design) that will allow passage through access ports without requiring removal of GSE cables, ducts, and access equipment also passing through the ports.

B. MOSC internal lighting for general illumination will be capable of being powered and turned on independently of MOSC subsystems by Ground Support Equipment prior to entry of ground crew personnel.

C. MOSC fans and other interior atmosphere circulating equipment be capable of continuous operation in a 1-g environment and be provided with a guard to prevent accidental contact from personnel.

D. The MOSC will not require men on board to accomplish pad check-out, monitoring, or other countdown activities.

E. The MOSC design will not require installation of flight hardware, other than ordnance initiators, on the pad.

F. All prelaunch and launch operations will be controlled by detailed procedures (manual, automatic or both).

G. Internal access to the MOSC will be controlled and limited.

H. MOSC design and operation will comply with the safety requirements of the launch site and range.

3.0 DOCKING SAFETY REQUIREMENTS

The following requirements for docking will apply:

A. All elements that dock to MOSC will have completely independent emergency thrustors with a separate propellant supply.

B. The capability will exist for activating emergency thrustors up to point-of-contact with MOSC in event of primary thrustor malfunction.

C. The predominant terminal docking method will be automatic; however, manual override capability will be provided.

D. Direct vision will be provided during docking. A view window will be provided in each docking port.

E. Redundancy or a backup restraining system will be provided as part of the docking mechanism.

F. Multiple docking ports will be provided.

G. All docking mechanisms will be the same design, i. e., all docking elements can dock at any port.

H. Shirtsleeve inspection, maintenance and repair of the docking mechanism will be provided.

I. Shirtsleeve transfer without removing the docking mechanism will be provided.

J. At least one docking port will be located on each normally inhabited compartment.

K. Each docking port will provide the capability for transferring crew and manually moving cargo.

L. Adequate lighting (including backup or emergency) will be provided to perform all expected docking operations.

4.0 COMMAND, CONTROL, AND EMERGENCY ACTION SAFETY REQUIREMENTS

The following safety requirements for command, control and emergency action will apply:

A. Time dependency will be eliminated as a factor of emergency action insofar as it is reasonable and practical to do so.

B. The initiation of emergency action and control of such action will be possible from the communication and control center. Local control will be available where necessary. Emergency action will be possible by more than one crew member.

C. An emergency communication system, independent from the normal intercom, will be provided to direct and control operational action during an emergency.

D. Manual override will be provided for all automatic life-essential and mission-survival functions.

E. Emergency lighting will be provided in all compartments independent of the prime power system.

F. Provision will be made so that an emergency situation can be isolated, contained, and controlled as far as practical.

G. Emergency oxygen masks will be provided in all compartments. These masks will have individual oxygen supplies as well as an umbilical that can be plugged into a central breathing oxygen distribution system.

H. Provisions will be made for selective fan cutoff and air duct closure.

5.0 AIRLOCK SAFETY REQUIREMENTS

The following safety requirements for airlock will apply:

A. Airlocks will be large enough to accommodate two men at the same time in pressure suits to enable both crewmen to ingress and egress rapidly in an emergency.

B. Airlock doors will allow rapid ingress and egress, will be operable from each side, and have a positive closure indication visible from each side.

C. Airlock mechanisms will be inoperable if pressure on each side are not equalized; however, manual override capability will exist within specified tolerances.

D. Compartment pressures will be indicated on each side of an airlock.

E. Windows and lights will be provided to allow complete observer coverage of airlock interior conditions.

F. Emergency control of pressurization and depressurization will be provided inside the airlock and outside.

G. Pressure relief valves or other safeguards will be provided to protect the chamber from structural damage in the event of over-pressurization.

H. Communications will be provided between men inside the airlock and MOSC and with EV crewmen.

I. Atmosphere/oxygen connections will be provided in each airlock for the maximum number of crew members planned to occupy the air-lock at one time.

J. Airlock will be provided between separately pressurized compart-ments.

K. More than one airlock leading to the exterior of the MOSC will be provided.

6.0 EVA/IVA SAFETY REQUIREMENTS

The following requirements for EVA/IVA safety will apply:

A. Umbilical connectors for IVA suits will be located in every pres-surizable compartment.

B. A pressure suit will be available for each crewman and in a readily accessible area.

C. Radiation detectors will be worn when performing EVA.

D. Emergency lighting will be provided to assist in rescue operations if EVA is required during the dark part of an orbit.

E. Continuous communications will be maintained by MOSC crewmen with EVA/IVA crewmen.

F. The MOSC will continuously monitor PLSS integrity (all critical life support functions) and physiologically vital functions.

G. Artificial-g operations will not be conducted during EVA.

H. Normal docking and movement of logistics cannisters and experi-ment modules will not be performed during EVA.

I. Attitude/rate corrections will not be performed during EVA.

J. The EVA pressure suit will be space-hardened for radiation and micro-meteoroids.

K. Handholds and guard rails will be provided to assist in scheduled EVA activities.

L. The EVA suit loop (PLSS) will not depend on the Space Station EC/LS.

M. Facilities for prebreathing oxygen (denitrogenation) will be readily available for all crewmen.

N. Unassisted EV ingress to the MOSC will be possible.

O. The EV and IV environment will be free of rough edges, projections and sharp edges that could snag a spacesuit.

P. Adequate protection will be provided for crew members performing IVA or EVA in proximity of a radioactive power supply.

Q. Assistance will be provided to EVA crewmen under any of the following conditions.

1. At the request of the EVA crewman.
2. When the crewman will not reenter the MOSC within a reasonable period after command.
3. When communication contact is lost and visual contact does not confirm acceptable status.
4. When an out-of-limit physiological condition is indicated.
5. When RF-monitored data and communications are list.

R. No EV tasks for planned maintenance or work purposes will require the crewman to enter an area within which he cannot rotate freely in a fully extended position.

S. EVA will be capable of surveillance, visual, or TV, from the MOSC at all times.

T. Redundant communication capability with EVA crewmen will be provided.

U. Ready access to eq ipment requiring maintenance by EV or IV activity will be provided.

7.0 INITIAL MANNING OPERATIONS SAFETY REQUIREMENTS

The following safety requirements for initial manning will apply:

A. Advance inspection of the MOSC will be performed by the minimum number of the initial crew (but not less than 2 crewmen).

B. The advance inspection crewmen will be in pressure suits and PLSS when initially boarding the MOSC.

C. A visual and photographic fly-around inspection will be performed by the Shuttle before initial docking to an unmanned MOSC.

D. The status of MOSC life-critical functions (atmosphere pressure, content, humidity, temperature, communications, power, guidance, and control, radiation levels, etc.) will be verified by Mission Ground Support and by visual display at the initial manning hatch before transferring the advance inspection crew.

E. The remaining crew will be physically isolated from the MOSC until the advance inspection crewmen verify that the MOSC is safe to receive the rest of the crew.

F. After transferring the initial crew and separation from the MOSC, the Shuttle will remain in the vicinity of the MOSC for 3 days.

8.0 HATCH SAFETY REQUIREMENTS

The following safety requirements for hatches will apply:

A. Docking hatches will provide a clear opening at least 5 ft. in diameter.

B. Hatches and doors between pressurized compartments will be fitted with latch and seal mechanisms operable from both sides.

C. Hatches will be provided with a mechanical alignment closing system, i. e., hinges or guides.

D. A view window will be incorporated in each hatch.

E. A prssure-equalizing valve will be provided at each hatch.

F. Instrumentation showing atmospheric condition on the opposite side of the hatch will be provided on both sides of each hatch.

G. Pressure seals will be replaceable on orbit.

H. Pressure seals will be redundant.

I. Hatches between compartments will be sized to accommodate an IVA-suited crewman.

J. A means of verifying positive hatch closure will be provided.

K. All docking port hatches will be maintainable (removable) from inside the MOSC.

9.0 MICROBIOLOGICAL SAFETY REQUIREMENTS

The following microbiological safety requirements will apply to a dedicated module/lab:

A. General

1. Only authorized personnel will be permitted in the laboratory.
2. No food or beverages will be allowed in the laboratory.
3. Books, journals, and personal items will not be taken into or out of laboratory except under specified controlled conditions.
4. Protective clothing will be worn in the laboratory.
5. A shower with germicidal soap prior to ingress and egress of the laboratory will be required.
6. A separate EC/LS for laboratory specimens will be provided.
7. The laboratory will be maintained at slightly lower pressure than the MOSC.
8. Provisions for emergency seal off of the laboratory will be made.

B. Disinfection and Sterilization

9. Infectious material will be immediately sterilized in an autoclave before disposal.
10. Floors and walls will be disinfected at least once a week and benches will be disinfected after each use where infectious substances are used.

C. Laboratory Equipment

11. All containers will be marked to indicate normal or inoculated animals, insects and viruses.
12. Ventilated safety cabinets will be used for opening containers with infectious substances.
13. Centrifuges will be enclosed in safety cabinets when centrifuging infectious substances.
14. Pipetting toxic/infectious materials by mouth will not be permitted.
15. Use of only Luer-Lox type syringes will be permitted.
16. Animal sites will be disinfected before and after injection.
17. Working alone on hazardous operation will not be permitted.
18. Protective gloves will be worn when handling or inoculating specimens.

19. Necropsy of infected animals will be performed in a ventilated safety cabinet or in an enclosed sterile bench area.

10.0 SENSOR, ALARM, AND WARNING SYSTEM SAFETY REQUIREMENTS

The following safety requirements will apply to sensors, alarm, and warning systems:

A. Systems and functions essential for safety will be monitored to provide detection and location of failures.

B. Warning indications will be activated for functions presenting an immediate threat to life.

C. Elements of the caution and warning system associated with warning functions will be completely separate from other onboard checkout equipment and sensors.

D. Warning indicators will be generated both visually and audibly.

E. Warning indicators will override all other communication traffic.

F. The capability of displaying more than one warning signal at the same time will be provided, i.e., one warning signal cannot block out receipt and display of other warning signals.

G. Complete circuit redundancy (sensors, wiring, switches, light, etc.) will be provided for warning signals. The capability will be provided for immediately detecting a warning circuit failure.

H. Warning signals will be provided in all inhibited areas of the MOSC.

I. Sensors and warning signals will be provided for select out-of-tolerance conditions (see Item A. 13-G). In addition to measurement of absolute values, changes at an excessive rate will also be indicated.

11.0 EXPERIMENT SAFETY REQUIREMENTS

The following safety requirements for experiments will apply:

A. Structural

1. All doors and hatches in the experiments areas will be fitted with release mechanisms operable from both sides.
2. Pressure hatch design will provide a means of visual verification that the hatch has been properly closed.
3. The module will use structural matrix with the capability of arresting crack and tear growth.

4. Hazards due to micrometeoroid penetration or module collision will be minimized by module wall design. Quick repair methods will be provided.
5. Suitable crew and equipment restraints will be furnished to allow crewmen to exert necessary forces to perform routine or maintenance work without personnel injury or equipment damage.

B. Propulsion

1. High-pressure vessels and volatile gas or propellant tanks will be located outside of, and as remote as possible from, crew-operating areas.
2. Interlock, automatic valves, or other means of isolation will be provided for liquid and gas systems so that a maintenance effort cannot inadvertently result in liquid or gas leaks or spills.
3. Where a propellant system can become contaminated, a means of contamination detection and crew alerting will be considered.
4. The commencement, behavior, and completion of all remote hazardous resupply operation (e.g., pressurized propellants or gas flow) will be positively monitored and statused at the appropriate spacecraft station.

C. Electrical

1. Any electrical equipment maintained by the crewmen and having a high-voltage hazard will be designed to be electrically isolated by interlocking switches or the equivalent before physical access to exposed connections and compartments is possible.
2. Connectors will be designed to preclude the possibility of mismating.
3. Mechanical shielding will be provided to protect electrical equipment, including wire bundles, from external physical damage.
4. Wire bundles will not be routed near potential heat sources.
5. Wires in a given bundle will be capable of carrying the design load of any other wire in that bundle without insulation breakdown.
6. Electrical insulation will be self-extinguishing in the module environment.

D. Atmospheric Control

1. While docked to the MOSC, the environmental state and habitability condition of inhabitable module compartments will be

displayed at the control station and visually determinable outside each point of entry. Appropriate indications of conditions in adjacent compartments will be displayed near the doors or hatches.

2. Sensors, compatible with those to be provided throughout the MOSC, are required in the experiment modules to detect and give warning of out-of-tolerance environmental gas components.
3. Readily available, individual, emergency, life-support equipment for the maximum crew members planned to occupy the experiment module at one time will be provided in that compartment.
4. A visual and aural alarm will be provided to warn of atmosphere contamination that exceeds specified limits.
5. The environmental control system for the animal experiment containment area will be designed to assure that no bacteria, odor, or physical contaminates (e.g., animal hair, food particles, waste products) can be introduced into the MOSC atmosphere.

E. Communication

1. The module will include crew communications systems compatible with MOSC systems for use during the docked and crew inhibited mission modes.

F. General

1. The module will be designed so that no single failure, other than primary structure, will cause a fatality to personnel.
2. The requirement for manual checkout of the experiment module during prelaunch test operations will be minimized.
3. Sensors will be installed in sensitive or danger areas to provide fire warnings. Fire suppressant techniques, such as fire extinguisher or automatic isolation and decompression of module compartments, will be considered.
4. Emergency lighting will be provided in all compartments independent of the prime power systems.
5. Safety-critical systems will be constantly monitored.
6. Module compartment walls will be accessible for inspection and repair. Sensors capable of sensing and locating micrometeoroid penetrations will be provided.

7. Intravehicular and extravehicular equipment will be designed to allow the astronaut ready access to items to be serviced or maintained.
8. Intravehicular and extravehicular environment will be free of rough edges, projections, or sharp corners that could snag a space suit or cause physical injury.
9. No extravehicular tasks for maintenance purposes will require the astronaut to enter an area or enclosed volume within which he cannot rotate freely in a fully extended position.
10. All overboard relief of dump valves will fail-safe in the closed position and will be self-indicating when failed.
11. Fluids required for the operation of subsystems and experiments located in pressurized compartments inhabited by the crew will be nontoxic and nonflammable.
12. Equipment and methods may be required to disinfect areas of the MOSC when medical opinion determines that there is a need to counteract a pathogenic threat to the crew.
13. The design of the animal experiment containment area, will assure that there is no unremedial befouling of the crewmen or contamination of the MOSC as a result of the crew interface in animal care, feeding, and experimental activity.
14. It is assumed to be a mission operational ground rule that no personnel will be inside an experiment module with the module or MOSC docking hatch closed.

G. Hazard Detection and Warning Subsystem

1. The hazard detection and warning subsystem will be designed to detect out-of-tolerance conditions for the following:
   a. Partial pressure (percent of O_2, N_2, CO_2)
   b. Total pressure.
   c. Temperature.
   d. Fire.
   e. Critical component (explosive, flammable, toxic).
   f. Relative humidity.

2. CO_2 sensors, will be distributed to ensure that pockets of high-concentration CO_2 not within prescribed limits for crew safety are detected. An alarm will be provided both in attached experiment modules and at the MOSC control station for all partial pressure sensors.
3. Total pressure sensors will monitor and detect out-of-tolerance values of total module pressure. Detection of pressure changes at an excessive rate will activate an alarm system in the module and at the MOSC control station.
4. Heat sensors located in the experiment module will give warning of incipient fire or out-of-tolerance condition for shirtsleeve entry.
5. Fire detectors will be designed to interface with the MOSC subsystems to warn of fire throughout the MOSC and to provide precise fire location to the control station.
6. An aural/visual subsystem will continuously monitor the environmental status for any hazardous materials used in conjunction with module experiments. This includes substances with explosive, flammable, or toxic characteristics.
7. A sensor will be provided to give visual indication at the control station when the atmospheric relative humidity in the experiment module is not within prescribed limits.

12.0 SHUTTLE SAFETY REQUIREMENTS

(See Shuttle Documentation)

13.0 CONFIGURATION, EQUIPMENT LOCATION SAFETY REQUIREMENTS

The following safety requirements for configuration, equipment location will apply:

A. Safety-critical equipment will be designed to allow emergency operation by employing redundancy and/or separation of parallel or similar functions, and the placing of such redundant or parallel equipment in isolation compartments or locations.

B. Hazards caused by micrometeoroid or collision damage resulting in penetration of the MOSC will be minimized by proper wall design.

C. Pressure cell walls will be readily accessible for inspection and repair.

D. Potentially explosive containers such as high-pressure vessels or volatile gas storage containers will be placed outside of and as remotely as possible from crew living and operating quarters, and whenever possible isolated.

14.0 MATERIALS SAFETY REQUIREMENTS

The following safety requirements for materials will apply:

A. If the use of toxic or dangerous (explosive, flammable, cryogenic) materials cannot be avoided on the MOSC, positive controls and safeguards will be provided such as:

1. Strict inventory and configuration control.
2. Subsystems in pressurized inhabited compartments use only nontoxic, nonflammable, noncorrosive fluids.
3. Special packaging and sealed containers.
4. Isolation of materials from normal operations (controlled access).
5. Use of test isolation facility for performance of experiments requiring these materials.
6. Monitoring system to indicate environmental status of the materials.

B. Materials used in the MOSC shall meet established NASA flammability criteria.

15.0 MAINTENANCE SAFETY REQUIREMENTS

The following safety requirements for maintenance will apply:

A. Valves, or other means of isolation, will be provided for liquid and gas systems so that a maintenance effort will not inadvertently result in liquid or gas leaks to the cabin.

B. Suitable restraints will be furnished to allow the crew to exert necessary forces in the zero-g environment with minimal risk of injury.

C. Electrical equipment which has a high-voltage hazard or which can result in inadvertent operation of critical functions while being maintained by the crew will be designed to be electrically isolated by interlocks or the equivalent before physical access will be possible.

Appendix B

SPACE SHUTTLE PAYLOAD ACCOMMODATIONS AND FLIGHT PERFORMANCE

Appendix B
SPACE SHUTTLE PAYLOAD ACCOMMODATIONS AND FLIGHT PERFORMANCE

As summarized in Table B-1, the Space Shuttle exercised a dominant influence on many characteristics of the MOSC configuration. To provide a ready reference for the reader, the following pertinent excerpts from the JSC 07700 Space Shuttle System Payload Accommodations - Level II Definition and Requirements Document (Volume XIV) are summarized in this Appendix.

B.1 (JSC 07700-12.0) PAYLOAD BAY

A 15-ft (4.572-m)-diameter by 60-ft (18.288-m)-long payload envelope is provided. This volume represents the maximum allowable payload dynamic envelope, including its deflections. This envelope is penetrated by the necessary payload structural attachments and umbilicals, which extend outside the envelope to the interface with the Orbiter. Clearance between the payload envelope and the Orbiter structure is provided by the Orbiter to prevent Orbiter deflection and deployment interference between the Orbiter and the payload envelope.

B.2 (JSC-07700-7.2/7.3) PAYLOAD ATTACHMENT LOCATIONS IN PAYLOAD BAY

Thirteen primary payload structural attachment points are provided along the payload bay as shown in Figure B-1. With the exception of the aft-most position, Xo = 1,303 in (33,096 mm), each attachment consists of three attachment points, one on each longeron (Zo = 414 in (10, 515.6 mm), Yo = ± 94 in (2,387.6 mm) and one at the keel (Zo = 305 in (7,747 mm), Yo = 0). The aft attachment consists of attachment points on the longerons (Xo = 1,303 in (33,096 mm), Yo = ± 94 in (2,387.6 mm), Zo = 409 in (10,388.6 mm), but none at the keel. With the exception of the attachment positions at Orbiter Stations Xo = 1,187 in (30,149.8 mm) and Xo = 1,246 in (31,648.4 mm), each set of three attachment points defines a plane normal to the payload bay centerline. At Station Xo = 1,187 in (30,149.8 mm) the keel fitting is at

Table B-1

SHUTTLE-ORBITER INTERFACE AND PERFORMANCE CHARACTERISTICS VERSUS MOSC REQUIREMENTS

Space Shuttle Operation Elements	Space Shuttle Characteristics	MOSC Study Application Primary	MOSC Study Application Secondary	MOSC Spacecraft, Subsystem or Operational Effect
1. Shuttle Orbiter Cargo Bay	1.1 Installation clearance envelope 15-ft dia x 60-ft long, less 7.5 ft for docking module leaves 52.5 ft clear installation length. (Ref. Docking Module, Para 1.4)	X		1.1 Controls the combined length of modules assembled for a single launch and the arrangement and length of specific modules and pallets.
	1.2 Payload installation structural support and mounting details		X	1.2 Preliminary basis for spacecraft mounting is equiva[illegible]t to the Spacelab mounting system ba[illegible]d on structurally determinant suppo[illegible]. Sufficient flexibility exists in the mounting provisions to meet the various module arrangements.
	1.3 Center of gravity envelope	X		1.3 Module and function relationships were arranged to meet the specified criteria within a ±20 percent tolerance on weights. Location of major components or consumables will ensure proper location of center of gravity.
	1.4 Docking module envelope and function	X		Primary method for attaching a MOSC module in orbit, supporting initial orbital checkout, crew transfer and rescue.
2. Prelaunch Operations	2.1 Horizontal access in orbiter processing facility - MOSC installed in Orbiter cargo bay (Ref. Para. 1.4)		X	2.1 Same basic access as Spacelab - through airlock and docking module.
	2.2 Vertical access on launch pad		X	(TBD)
3.0 Launch and Landing Loads	3.1 Launch loads		X	3.1 MOSC is not limited by the 65k launch capability
	3.2 Landing loads	X		3.2 MOSC core vehicle gross weights including ≈15 days of consumables are within ±10 percent of the 32 klb for the heaviest modular assembly. which meets the planned Shuttle Orbiter landing load requirement. however, MOSC core vehicle modules are not intended to be returned in other than an emergency situation.
4.0 Orbital Mission Operations	4.1 MOSC deployment with the Remote Manipulator System	X		4.1 Deployment from Shuttle Orbiter bay is with the Remote Manipulator System, which docks the MOSC to the Docking Module.
	4.2 Final subsystem checkout and crew transfer		X	4.2 Docking interface on Docking Module would provide checkout control and data transmission and allow IVA crew transfer.
	4.3 Orbital rendevous and docking	X		4.3 - Shuttle docking dynamics were used in sizing MOSC propulsion subsystem - Shuttle RCS payload contamin-a[illegible]n potential identified during study
	4.4 Shuttle performance	X		4.4 Shuttle payload capability versus altitude determined maximum operational altitude
	4.5 Single Remote Manipulator System	X		4.5 Necessitates utilization of Orbiter Docking Module for most orbital assembly/disassembly operations

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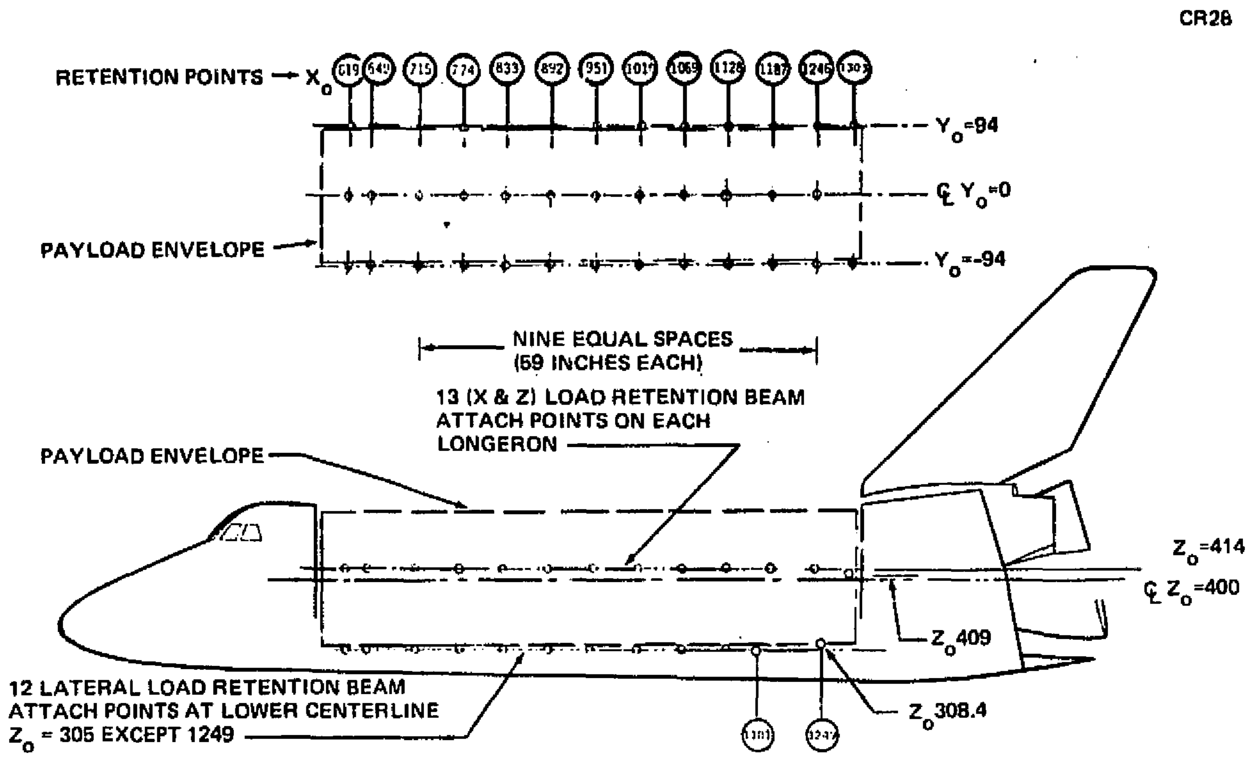

Figure B-1. Payload Primary Attachment Locations

Station Xo = 1, 181 in (29, 997.4 mm); at Station Xo = 1, 246 in (3, 168.4 mm), the keel fitting is at Station Xo = 1, 249 in (31, 724.6 mm). These longeron attachment points have provisions for remote control latching fittings and may be used by either deployable or nondeployable payloads.

The Orbiter provides the load-carrying capability for special vernier bridges which accommodate bolt-down payload fittings at a spacing of 11.8 inches (299.72 mm). Potential locations on the longeron for bolt-down fittings are shown in Figure B-2. This figure identifies both the primary and vernier attachment locations. The primary is identified with a double circle and the vernier locations with a single circle. A co-planar keel-fitting is not provided at all locations.

Payload Baseline Attachment Concept — A four-point retention concept, as shown in Figure B-3, provides a statically determinate mounting. The attachment fittings along the longeron react loads in either the ±X and ±Z

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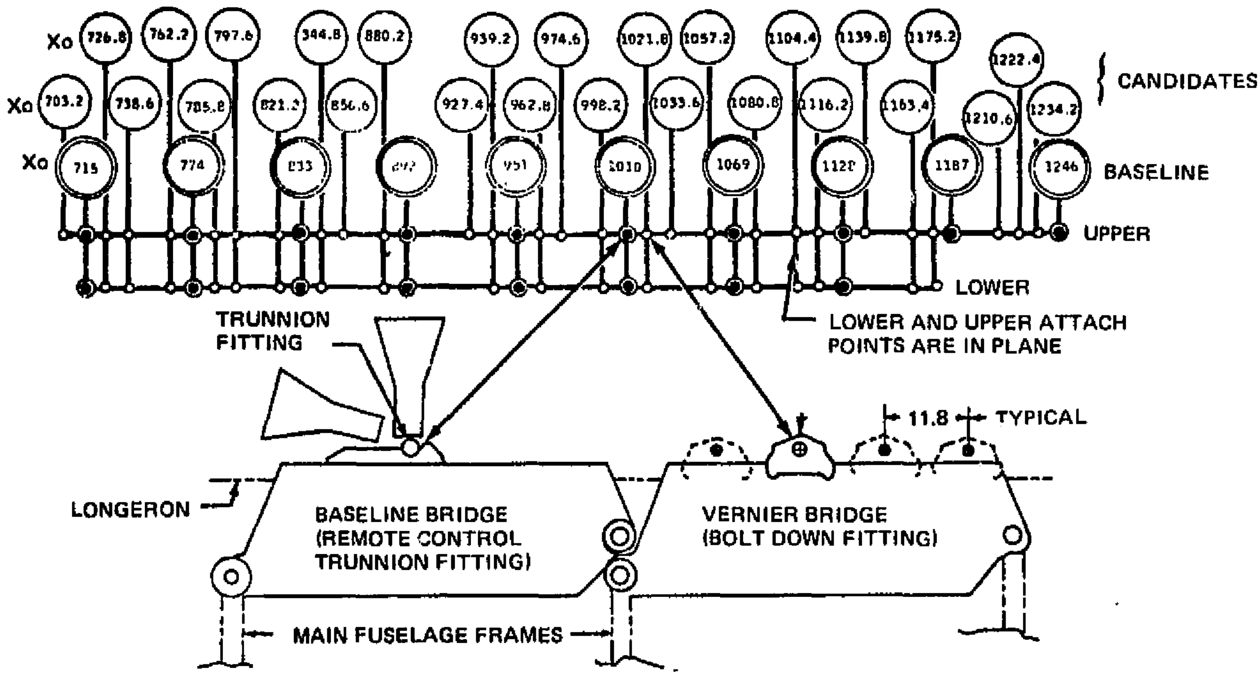

Figure B-2. Potential Locations for Non-Deployable Payload Primary Attachment Fittings

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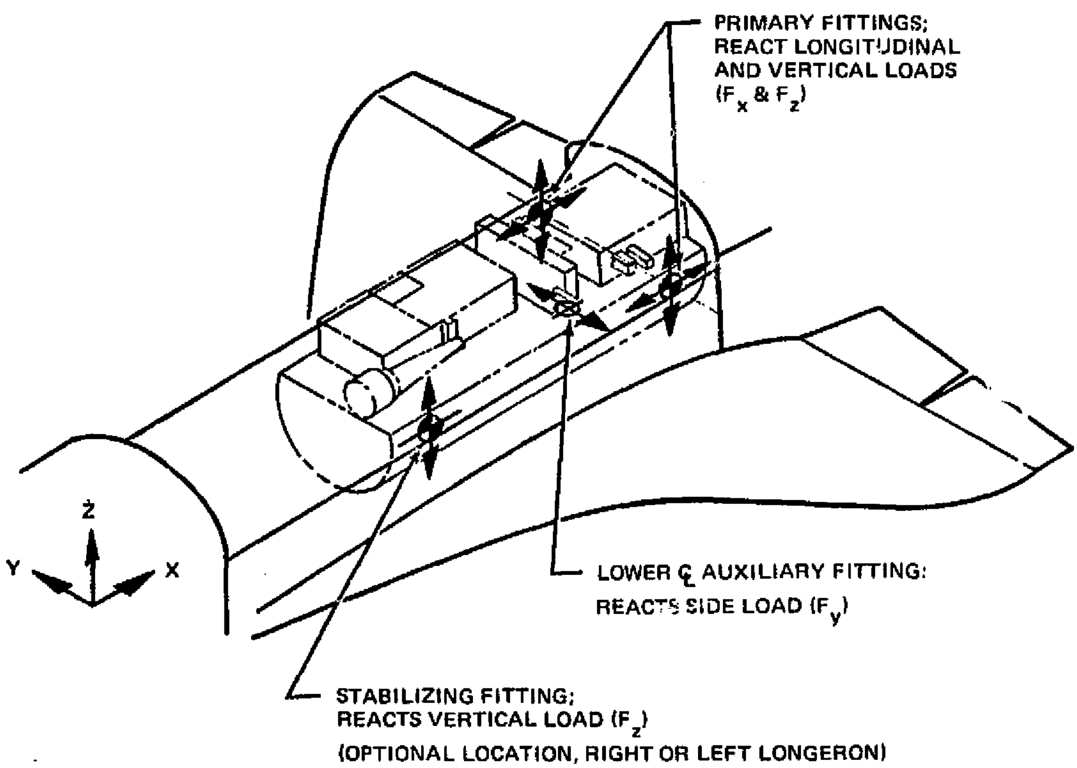

Figure B-3. Payload Retention System

directions (primary) or the ±Z directions (stabilizing), while the lower keel fittings react loads in the ±Y direction (auxiliary) only. Keel fittings at Orbiter Xo Stations 715 (18, 161 mm), 951 (24, 155.4 mm), 1, 069 (27, 152.6 mm), and 1, 181 (29, 997.4 mm) will react ±X loads in addition to ±Y loads as shown in Table B-2. The stabilizing fitting may be located on either the left or right longeron. The Orbiter-supplied interface fittings will minimize Y loads in the primary fittings, X and Y loads in the stabilizing fittings, and X and Z loads in the keep fittings. Statically indeterminate payload attachment methods shall not be precluded, but such methods must be compatible with the structural and mechanical capability of the Orbiter attach points for all combinations of deflections and loads.

Table B-2

LIMIT LOAD CAPABILITY AT PRIMARY AND VERINER AUXILIARY (KEEL) FITTINGS

STATION Xo, INCHES	±Y LIMIT LOAD 1000 LBS	±X LIMIT LOADS 1000 LBS
619	9.33	
649	18.18	
* 715	32.76	2.5
726.8	21.99	
738.6	15.98	
762.2	33.79	
* 774.0	45.88	
785.8	30.64	
797.6	23.12	
821.2	39.87	
* 833.0	55.60	
844.8	38.26	
880.2	38.53	
* 892.0	59.80	
939.2	49.49	
* 951.0	70.20	7.5
962.8	51.36	
998.2	57.64	
*1010.0	90.80	
1021.8	57.99	
1057.2	50.71	
*1009.0	78.50	6.0
1080.8	55.52	
1104.4	25.20	
1116.2	37.35	
*1128.5	72.50	
1163.4	24.60	
1175.2	42.74	
*1181.0	67.52	1.5
1249.0	56.4	

*Primary Station

B. 3 (JSC-07700-7. 1) CARGO CENTER OF GRAVITY ENVELOPES

Center of gravity envelopes are provided for a cargo up to a maximum of 65,000 lb (29,510 kg). The allowable longitudinal, vertical, and lateral composite payload (cargo) center-of-gravity envelopes are given in Figures B-4 through B-6. All payload chargeable items (OMS, kits, EPS kits, spare parts, etc.) regardless of location, i.e., payload bay, beneath bay, etc., must be included in the computation to obtain the location of the cargo center-of-gravity.

The cargo center-of-gravity for weights up to 65,000 lb (29,510 kg) must be within the specified envelopes at the time of main engine cutoff-MECO for RTLS abort and at the time of entry (400-kft altitude) for all other intact abort flight modes. For normal missions, the cargo center-of-gravity for weights up to 32 klb (14,528 kg) must be within the specified envelopes at the time of entry – 400 kft (122,000 m) altitude.

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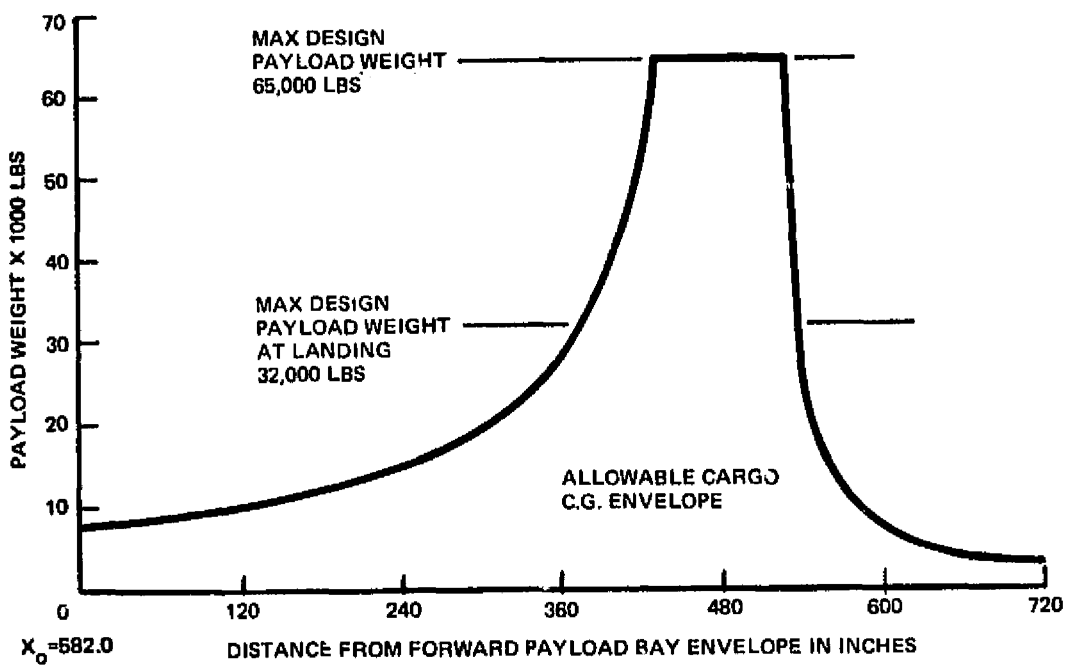

Figure B-4. Cargo CG Limits (Along X-Axis)

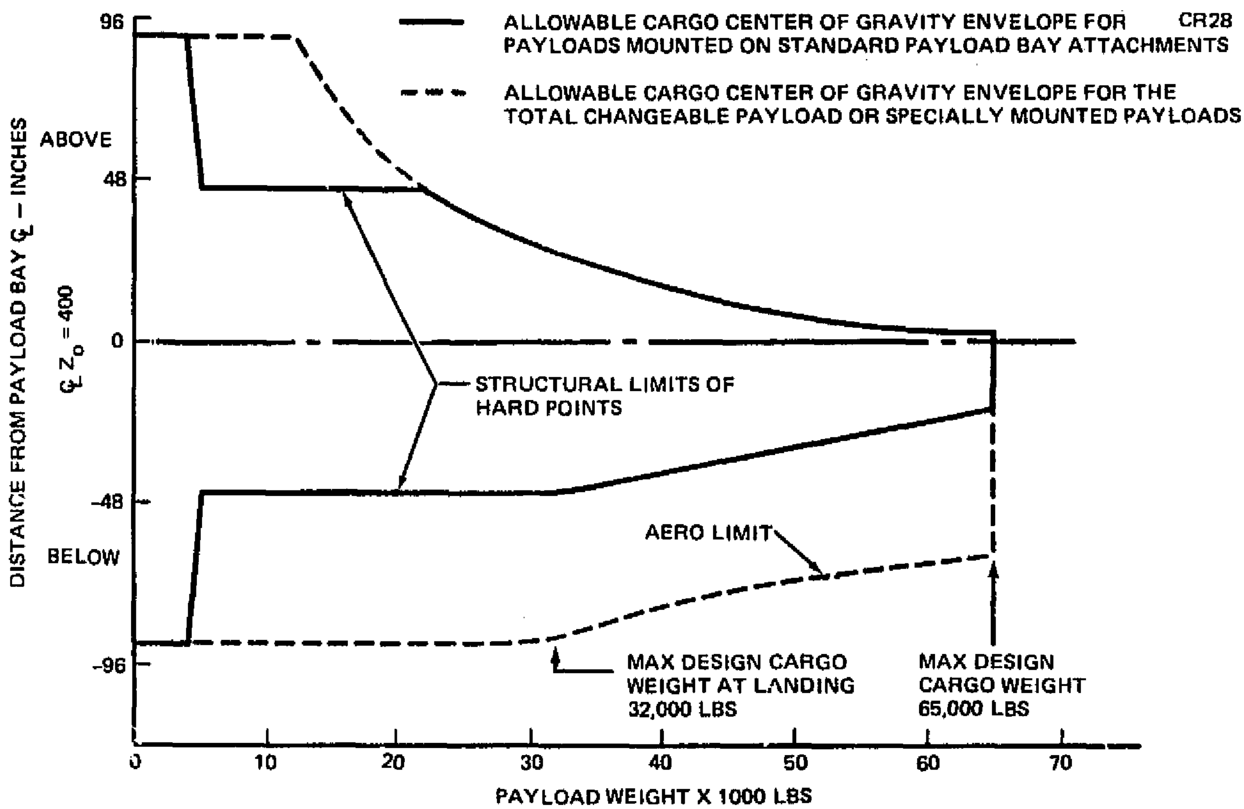

Figure B-5. Cargo CG Limits * (Along Z-Axis)

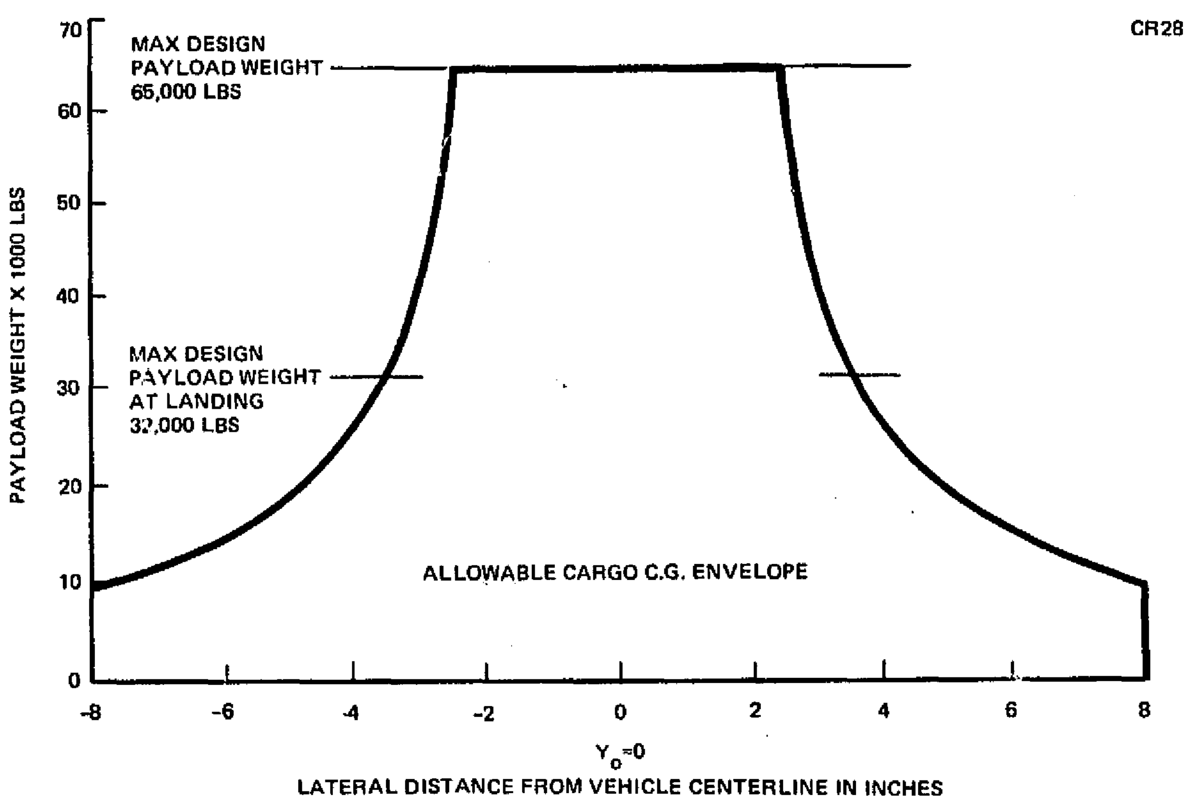

Figure B-6. Cargo CG Limits (Along Y-Axis)

B. 4 (JSC-07700-13. 4) DOCKING MODULE

The Orbiter may be docked to another orbital element by using the Docking Module installed in the payload bay as a payload weight chargeable item. This module is attached to the Orbiter airlock with access provided by the payload bay hatch. A 40-inch clear diameter passageway is provided through the Docking Module, either to the payload bay or to an attached habitable payload. Typical installation is shown in Figures B-7 and B-8. EVA is possible with either configuration, with access to the exterior through the docking interface hatch. The size object that can be moved to or from the habitable payload by an unsuited crewman is 22 x 22 x 50 inches and 18 x 18 x 50 inches for EVA suited operations to or from the payload bay. The interface between the docking module and a tunnel as shown in Figure B-8 is similar to the airlock interface, as shown in Figure B-9.

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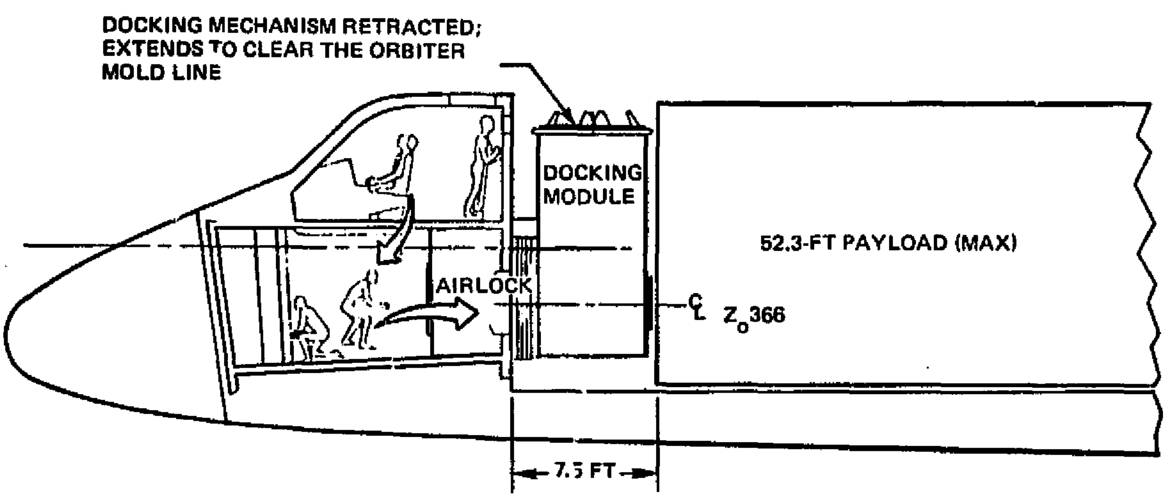

Figure B-7. Orbiter Airlock/Docking Module Interface

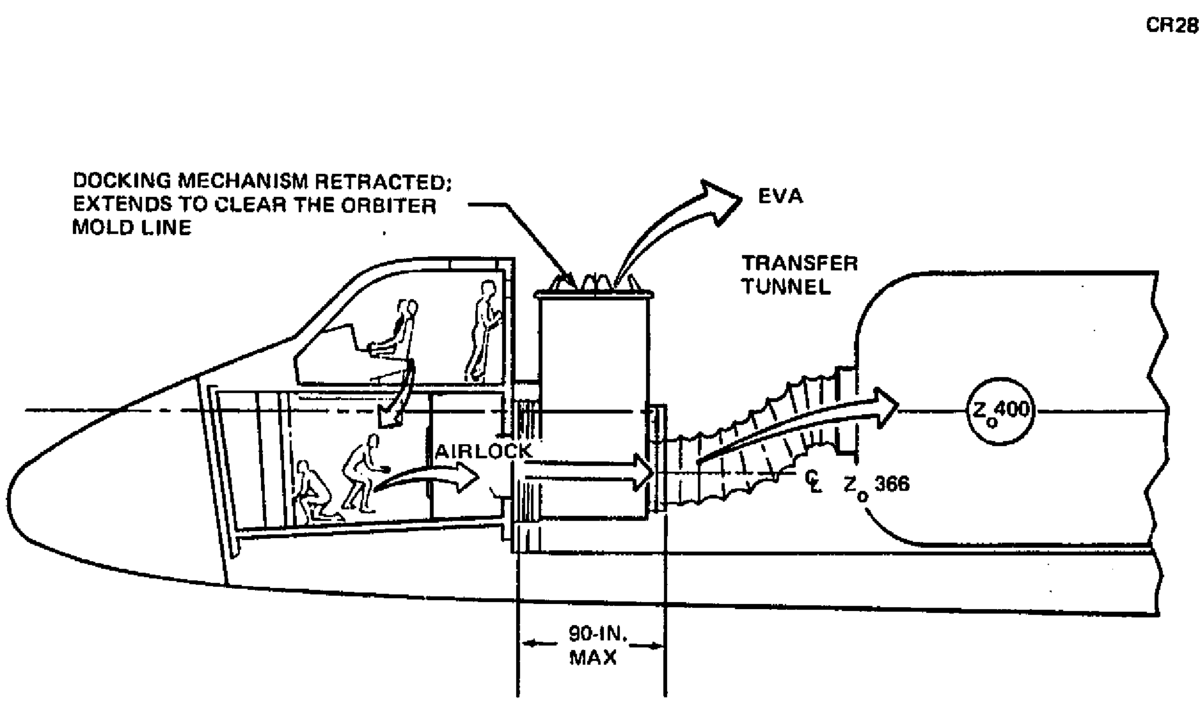

Figure B-8. Orbiter Airlock/Habitable Payload Interface with Docking Module

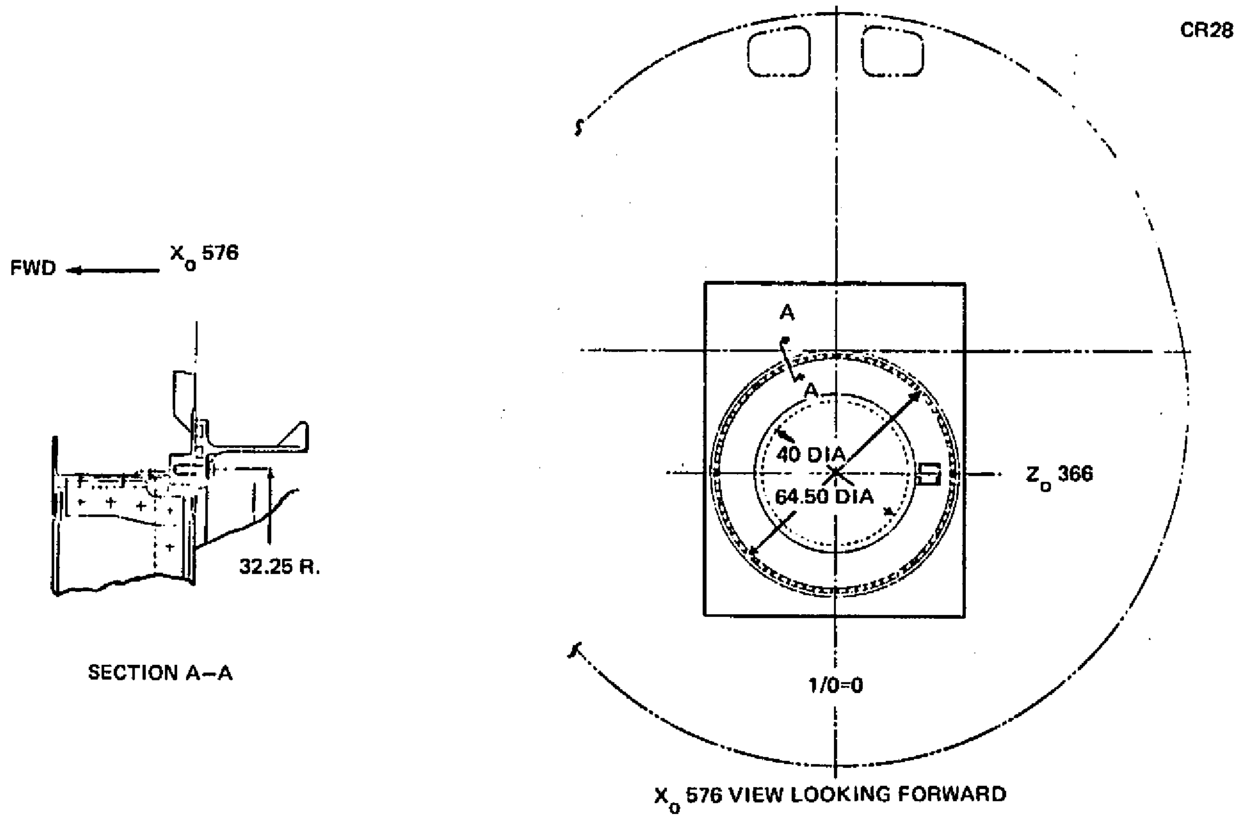

Figure B-9. Payload Bay Hatch and Tunnel Standard Interface

Appendix C
SKYLAB CANDIDATE HARDWARE SUMMARY

Appendix C
SKYLAB CANDIDATE HARDWARE SUMMARY

Early in the MOSC Study, a survey was made of Skylab hardware items which would be available for use in extended duration missions or which represent current technology upon which extended missions would be predicted. This appendix itemizes the applicable Skylab systems. The format used is as follows:

1. The first column indicates the element of the Skylab Program which contains the unit. Abbreviations used are:

   ATM - Apollo Telescope Mount

   AM - Airlock Module

   MDA - Multiple Docking Adapter

   OWS - Orbital Workshop

2. The second column lists the unit and some general characteristics. All abbreviations should be self-explanatory.
3. Additional information on the units itemized can be obtained from the "Skylab Operations Handbook (SLOH)," Document No. MSC 04727, dated 24 January 1972

A. STRUCTURAL AND MECHANICAL

Source	Subsystem
ATM	Payload Shroud (3 section) Cylinder assembly 260 in. dia by 350 in. long Aft cone 142 in. long (cone angle - 12-1/2° Fwd cone 182 in. long (cone angle - 25°) Provides structural support Separates on command
ATM/AM	Discone Antenna Booms Contains two booms - deploys to 36 ft 8 in.
ATM	Apollo Telescope Mount Deployment assembly and rotation system
AM/MDA/OWS	Pressure Hatches MDA - 30 in. diameter AM - 49.5 in. dia with 8.5 in. dia window OWS - 42 in. diameter
AM/MDA/OWS	Windows MDA - IR reflective with window cover AM - 8 in. x 12 in. oval IR reflective with cover OWS - 18-5/6 in. circular IR and UV coated
OWS	Radiator Surface area - 84 sq ft Heat transfer - 1,680 Btu/hr Operating pressure - 140 psia maximum

B. ENVIRONMENT CONTROL AND LIFE SUPPORT (INCLUDING FOOD, WATER, AND WASTE MANAGEMENT)

Source	Subsystem
OWS	Relief Valve Cracking pressure - 5.5 to 6.0 psid Effective area - 0.47 sq in.

Source	Subsystem
OWS	Cabin Pressure Regulator Assembly Regulated pressure - 4.8 to 5.2 psia Flow rate - 1 lb/hr minimum Inlet filter - 10 microns
OWS	PPO_2 Sensor, Amplifier, Controller Sensor range - 0 to 6.4 psi Control range - 3.3 to 3.9 psi
OWS	Coolant Pump Assembly Flow rate (1 pump) - 230 lb/hr Operating pressure - 100 psig
OWS	Radiant Heater Heat dissipation - 125 W at 24 Vdc Voltage range - 22 to 28 Vdc Surface temperature - 210°F
AM	Thermal Capacitor Melting point - 22.35°F 66.5 Btu/lb. Flow rate - 220 lb/hr at 75°F
AM	Ground Cooling Type Heat Exchanger Operating pressure - 230 psig maximum Heat transfer - 17,700 Btu/hr
AM	Regenerative Heat Exchanger Operating pressure - 203 psig Heat transfer - 4,720 Btu/hr
AM	Cold Plate Operating pressure - 100 psig Thermal conductance - 50 Btu/hr
ATM	Cooling Pump Flow rate - 220 lb/hr Power - 30 W at 28 Vdc

Source	Subsystem
ATM	Water Filter Operating pressure - 60 psig maximum Flow rate - 0.5 gpm Filtration - 10 microns minimum 25 microns absolute
AM/MDA/OWS	PLV Fans Operating pressure - 4.8 to 14.7 psia Power - 13 W at 30 Vdc
AM	Molecular Sieve Fan Operating pressure - 5.5 psi maximum Flow rate - 34.2 cfm
AM	Solids Traps Operating pressure - 5.5 psig Flow rate - 17.1 cfm
AM	Charcoal Canister Flow rate - 18.2 lb/hr
AM	Suit Cooling Pump Flow Rate - 200 to 350 lb/hr Power - 30 W
AM	EVA/IVA Gas Separator Flow rate - 200 to 350 lb/hr Gas removal - 95% of 20 ± 2 sccm influent gas
OWS	Thermal Capacitor Flow rate - 125 lb/hr Operating pressure - wax side - 40 psia maximum coolant side - 140 psia maximum
OWS	Pump Package Operating pressure - 100 psig maximum Flow rate - 125 ± 11 lb/hr Power consumption - 70W
OWS	Freezers Flow rate - 125 lb/hr Operating pressure - 100 psig

C. ELECTRICAL POWER

Source	Subsystem
OWS	Solar Array 147,840 cells at 113 mW/cell Total power 1700 W Minimum voltage 58 V
AM	Battery 33 amp-hr 30 series connected NICAD cells Charging voltage range - 30 to 48 Vdc Discharge voltage range - 30 to 36 Vdc Environment - -10° to +120°F Pressure relief built in
AM	Battery Charger Input voltages (solar array) - 30 to 125 Vdc (battery) - 30 to 42 Vdc Input power (solar array) - 2,580 W
AM	Bus Voltage Regulator Input (solar array) - 30 to 125 Vdc (charger) - 33 to 48 Vdc Output (open circuit) - 26 to 30 Vdc (at 50 amps) - 24 to 28 Vdc

D. COMMUNICATIONS

Source	Subsystem
AM/MDA/OWS	Intercom Box Input voltage - 22 to 30 Vdc Maximum input power - 15.9 W Minimum microphone input - 75 db Speaker output - 0 to 106 db at 5 psia
AM	Audio Load Compensator Input voltage - 22 to 30 Vdc Output power - 5.4 W Operates with microphone amplifier, earphone amplifier and tape recorder amplifier

Source	Subsystem
AM/MDA/OWS	Television (Used with Apollo TV Camera)
	TV Input Station
	Input voltage - 22 to 30 Vdc Input power - 9.1 W Video amplification - 6 db to 14 db Video output - 4 V P-P
	Video Selector
	Input voltage - 22 to 30 Vdc Input Power - 5 W Video Amplification - 0 to 12 db Video output - 3.5 V P-P
AM	Teleprinter
	Input voltage - 28 to 30 Vdc Maximum input power - 25 W Print characteristics 63 alphanumeric characters Each character - 0.153 in. high 30 characters/line Print rate - 18 characters/sec
ATM	Ranging Antenna (VHF)
	5 turn helix 259.7 to 269.5 MHz
AM	VHF Transceiver
	Receiver - 259.7 MHz Transmitter - 296.8 MHz
ATM/AM	Command Antennas - 450 MHz
ATM/AM	Launch Stub Antennas - 230.4 to 450 MHz
AM	2 watt Transmitter
	Input voltage - 22 to 30 Vdc Input power - 18.9 W Frequency - 230.4 MHz
AM	10 watt Transmitter
	Input voltage - 24 to 30 Vdc Input power - 81 W Frequency - 230.4 MHz, 246.3 MHz, 235.0 MHz

E. DATA MANAGEMENT

Source	Subsystem
AM	DC-DC Converter Input voltage - 18 to 30.5 Vdc Input power - 113 W Output voltages, +24 Vdc (10 to 40 W) -24 Vdc (7.5 to 30 W) +5 Vdc (0.12 to 1.5 W)
AM	DC-DC Converter Input voltage - 19 to 34 VDC Input power - 29 W Output voltages - +24 Vdc (0 to 8 W) -24 Vdc (0 to 5 W) +5 Vdc (0 to 1 W)
OWS	DC-DC Converter Input voltage - 24 to 30 Vdc Input power - 6 W Output voltage - +5 Vdc (0 to 1 W)
MDA	Signal Conditioner Input voltage - -24 to 30 Vdc Input power - 5 W
AM	Programmer Input voltage - -24 Vdc Input power - 6.3 W Inputs - 9 L/L at 80 sps 6 L/L at 160 sps 6 H/L at 10 sps 32 H/L at 1.25 sps 24 Bit Digital at 0.416 sps 8 Bit digital at 10 sps Outputs - 51.2 KBPS NRZ-C (serial) 5.12 KBPS RZ (serial) 5.12 KBPS clock (serial)
AM	Interface Box Input voltage - -24 Vdc Input power - 18.3 W Inputs - 18 H/L at 10 sps 5 H/L at 20 sps 1 H/L at 40 sps 8 H/L at 80 sps 5 H/L at 320 sps Outputs - 5.12 KBPS RZ (serial)

Source	Subsystem
AM/MDA/OWS	Low-Level Multiplexer Input voltages - +18 VDC, -18 Vdc, +5 Vdc Input power - 0.036 W (+18 Vdc) 0.043 W (-18 Vdc) 0.060 W (+5 Vdc) Inputs - 8 L/L at 1.25 sps 24 L/L at 0.416 sps
AM/MDA/OWS	High Level Multiplexer Input voltages - +5 VDC, -5 Vdc Input power - 0.050 W (+5 Vdc) 0.020 W (-5 Vdc) Inputs - 32 H/L at 1.25 sps 24 B/L at 10 sps 16 BLP at 10 sps
AM	Tape Recorder Input voltage - 24 ± 1% Vdc Input power - 15.5 W maximum Inputs - 5.12 KBPS RZ and clock 5.76 KBPS RZ and clock 300 to 3,000 Hz audio Outputs - 112.6 KBPS NRZ-Space 126.7 KBPS NRZ-Space 6.6 to 66 KHz
AM	Quartz Crystal Micro Balance Input voltage - 23.25 to 24 Vdc Input current - 35 milliamps maximum Sensitivity - 45 MVDC/microgram Output impedence - 10K ohms Life - 9,000 hr Operation temperature - -70°F to 160°F
AM	Receiver - Decoder Input voltage - 22 to 33 Vdc Input power - 12.5 W Receiver frequency - 450 MHz
AM	Digital Control System Relay Module Input voltage - Set - 23 Vdc Reset - 18 Vdc Coil currents - Set - 0.02 amp Reset - 0.01 amp Channels/Relay Module - 8

c 4

Source	Subsystem
AM	Command Relay Driver Unit Input voltage - 22 to 30 Vdc Input power - 40.5 W Output (480 relay drivers) - 0.85 amp
AM	Electronic Timer Input voltage - 22 to 30 Vdc Input power - 7.2 W Accuracy - 0.125 sec/day Capacity - Elapsed time - 582 hr, 32 min Time-to-go - 2 hr, 16 min Time-to-go - 582 hr, 32 min
AM	Time Correlation Buffer Input voltage - 22 to 30 Vdc Input power - 17.8 W Accuracy - 0.125 sec/day
AM	GMT Clock Input voltage - 22 to 30 Vdc Input power - 10.8 W Accuracy - 0.125 sec/day Capacity - 400 days
AM	Event Timer Input voltage - 22 to 30 Vdc Input power - 4.3 W Accuracy - 0.125 sec/day Capacity - 1,000 hr
AM	Portable Timer Input voltage - 1.4 Vdc, 5.4 Vdc Input power - 1 W Accuracy - 0.6 sec/day Output tone - 800 Hz at 70 db
AM/MDA/OWS	UV Fire Sensors Input voltage - 18 to 33 Vdc Input power 6 W Sensitivity - 1,850 to 2,650 A°
AM/MDA/OWS	Rapid ΔP Sensors Input voltage - 18 to 34 Vdc Input power - 5.6 W

F. STABILIZATION AND CONTROL

Source	Subsystem
OWS	Spheres
	Volume - 4.5 cu ft Operating temperatures - -15° to +173°F Operating pressure - 300 to 3,100 ± 100 psia Proof pressure - 6,000 psig Burst pressure - 8,000 psig
OWS	Control Valves
	Operating pressure - 0 to 3,200 ps. Proof pressure - 4,800 psig Burst pressure - 8,000 psig Life - 35,000 cycles Solenoid voltage - 24 to 30 Vdc Solenoid current - 3 amp maximum
OWS	Thruster
	Expansion ratio - 50 Environmental - -140° to +165°F Life - 35,000 cycles

G. CREW ACCOMMODATIONS

Source	Subsystem
AM/ATM	EVA Light
	20 W, incandescent, white Grid enclosed Directional lens
AM/MDA/OWS	Internal Floodlight
	8 W flourescent 10 W incandescent 20 W incandescent
OWS	High Intensity
	37.5 W flourescent

Source	Subsystem
OWS	Stowage Compartments 1 cu ft 1.5 cu ft 3 cu ft 6 cu ft 6.5 cu ft
OWS	Food Boxes 8 cu ft
OWS	Food Freezer or Chiller Holds 28 day supply for 3 men Freezer temperature: -10°F Chiller temperature: +45°F
OWS	Urine Freezer Holds 56 day accumulation for 3 men
OWS	Galley Holds 7 day food supply for 3 men
OWS	Water Tanks Holds 650 lb water, 600 lb usable Pressure required - 35 psig Heater blankets maintain water at 50°F
OWS	Portable Water Tank Capacity - 3 gallons Self-contained
OWS	Safety Aids Medical support kit Van Allen belt dosimeter Fire extinguishers

H. DOCKING

Source	Subsystem
AM/MDA/ATM	Docking Lights
	20 W, incandescent, red 20 W, incandescent, green 20 W, incandescent, white 20 W, incandescent, amber 0.7 W, incandescent, white
ATM	Tracking Lights
	High intensity, flashing Visibility - 3rd magnitude star at 269 nmi
MDA	Docking Alignment Target
	Apollo LM Type Base diameter - 17.68 in. Self-illuminating
MDAC	Docking Port and Mechanism
	Apollo drogues and rings Consists of tunnel, drogue, hatches

Appendix D
SHUTTLE ATTACHED MODE SUMMARY

Appendix D
SHUTTLE ATTACHED MODE SUMMARY

In order to assess the feasibility of extending the Shuttle Spacelab mission duration beyond 30 days, a shuttle attached manned orbital systems concept was examined early in the MOSC study. In this analysis, four Spacelab configurations (as shown in Figure D-1) were considered for the extended mission and projections were made from data appearing in the Shuttle and Spacelab Payload Accommodations Handbooks*. In determining launch and landing weight indications, a total of four crewmen (plus Orbiter crew) and an electrical power requirement of 15.3 kW (assuming fuel cells providing 8.3 kW to the Orbiter and 7.0 kW to the Spacelab) were considered as the baseline requirements for extended missions.

The discretionary payload weight for each Spacelab configuration is quoted in the Spacelab Payload Accommodation Handbook, which is referenced to a design-to-weight requirement of 25 klb total launch weight including the discretionary payload allowance. The difference between the 25 klb and the discretionary payload weight was then assumed, for purposes of this analysis, to be the basic Spacelab weight for each configuration referenced.

In terms of payload support and accommodations, the configurations are: Configuration 1 - long Module; Configuration 2 - short Module and three pallets; Configuration 3 - 5 Pallets only; and Configuration 4 - 3 Pallets only. The first two configurations, for purposes of preliminary analysis, can be considered to have the same payload support capability in terms of weight. Weight summaries for these four configurations are presented in Figures D-2 through D-7. A 10 percent contingency is included in the weight data.

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*References: Space Shuttle System Payload Accommodations Level II Vol XIV - JSC-07700 - Rev C and Spacelab-Payload Accommodation Handbook, (preliminary issue) Oct 1974 ESTEC Ref No. SLP/2104

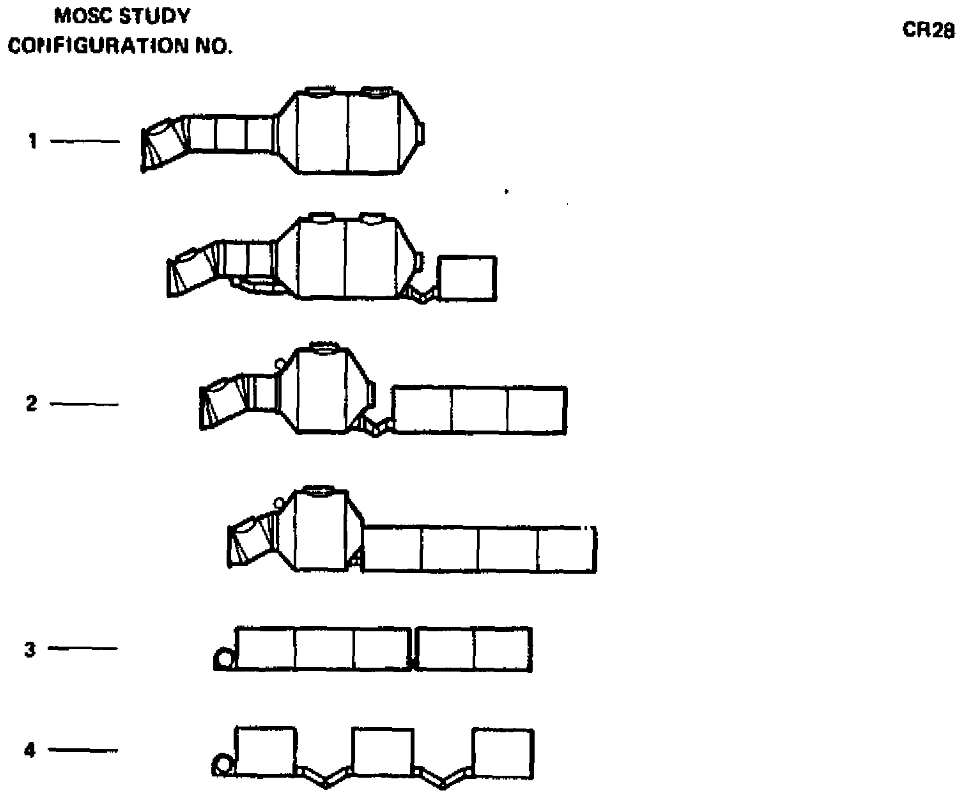

Figure D-1. Spacelab Baseline Configurations

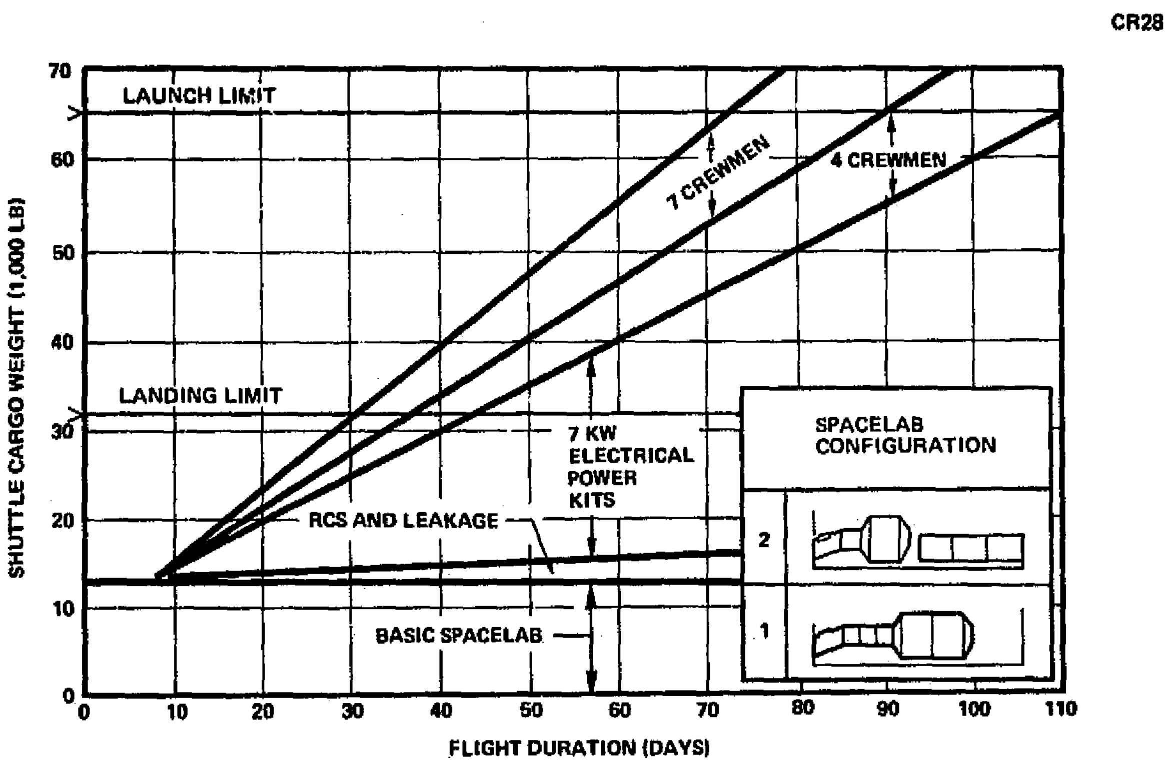

Figure D-2. Spacelab Extended Capabilities

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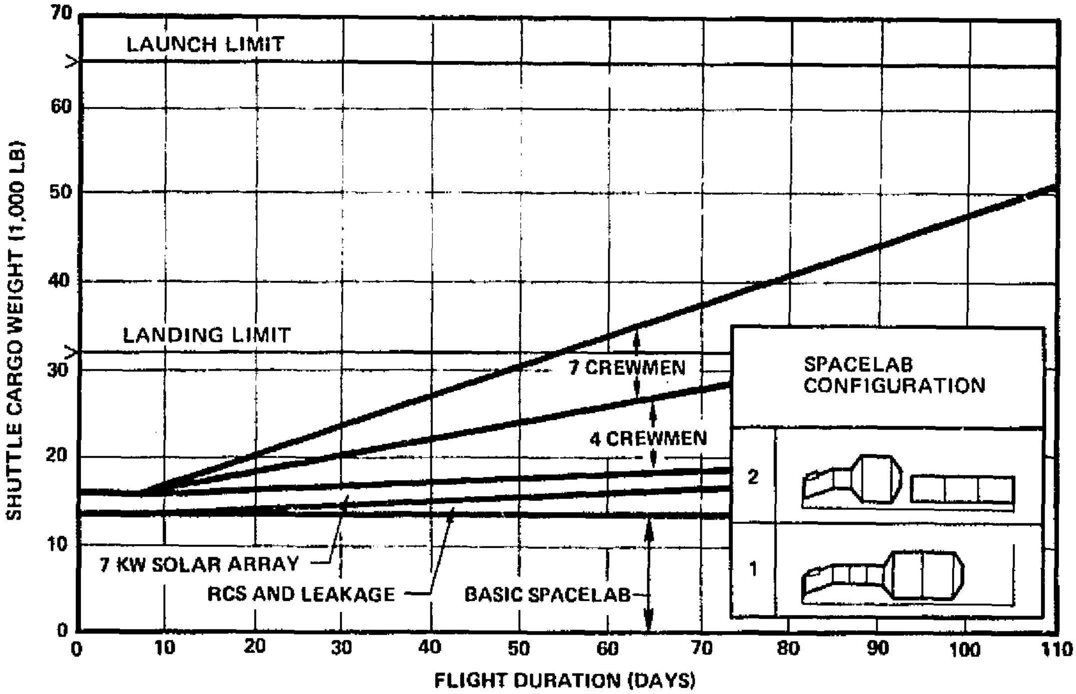

Figure D-3. Spacelab Extended Capabilities – Solar Powe' Modification

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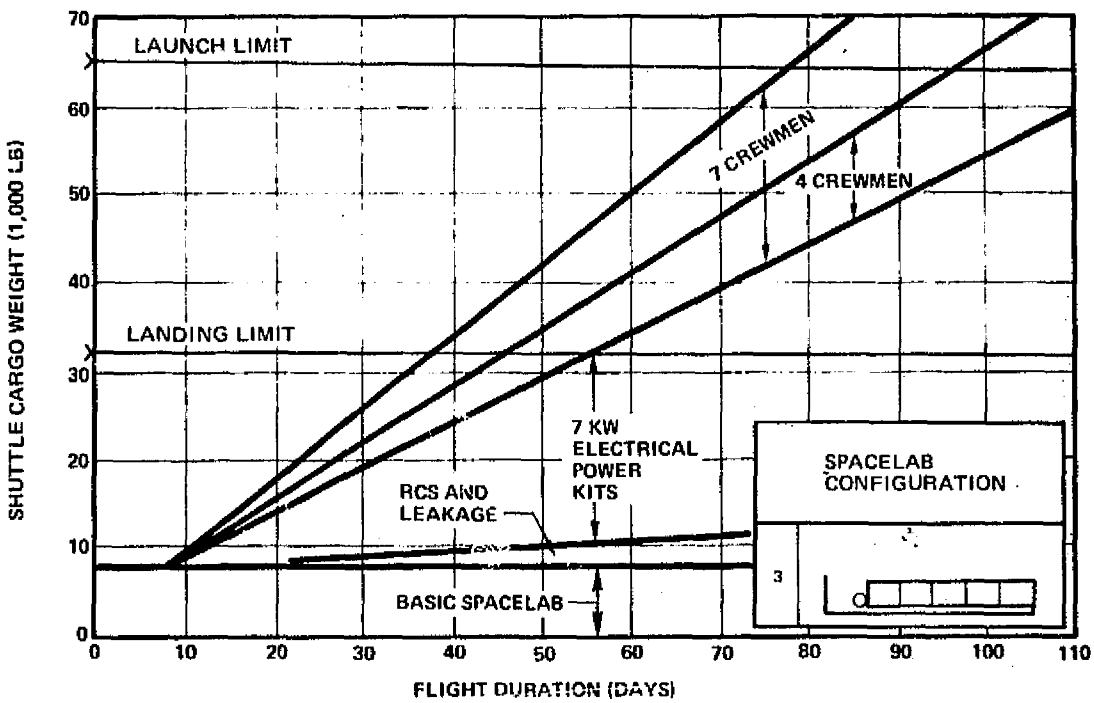

Figure D-4. Spacelab Extended Capabilities

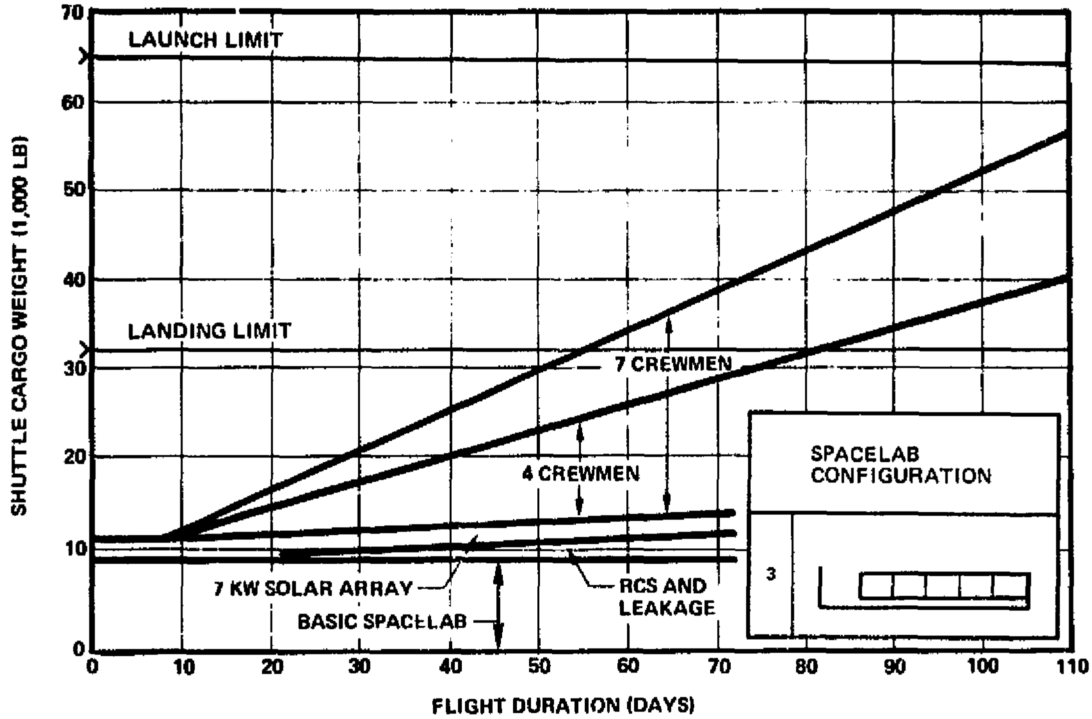

Figure D-5. Spacelab Extended Capabilities — Solar Power Modification

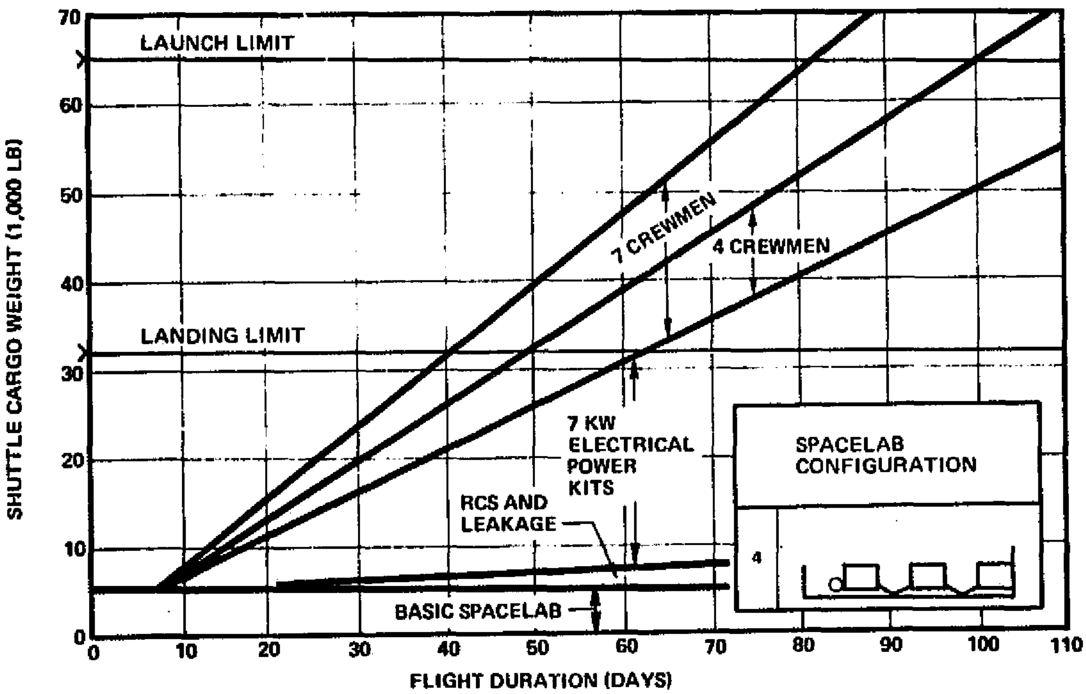

Figure D-6. Spacelab Extended Capabilities

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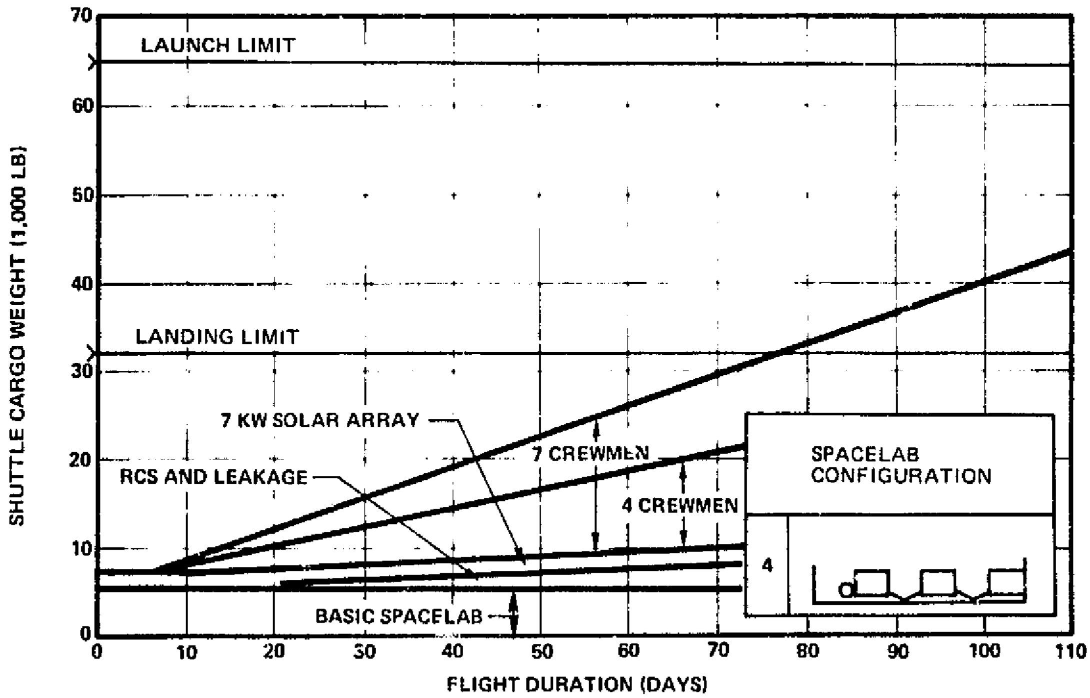

Figure D-7. Spacelab Extended Capabilities — Solar Power Modification

Figures D-2, D-4, and D-6, respectively, display detail data for the four Spacelab configurations flight extension capabilities relying on Orbiter fuel cells to supply electrical power needs. Figures D-3, D-5, and D-7 are indicative of potential improvement in capability by substitution of solar arrays as a source of additional electrical power. Installation concepts for the lightweight foldout arrays were not developed, but it is noted that such arrays would occupy payload volume in the cargo bay of the shuttle and might present potential interference with payload viewing requirements.

In estimating the weight growth requirements the same factors were utilized in each case as flight times were extended, for the four configurations. The assumptions made and procedures used in the determination of the estimates are as follows:

1. The Shuttle reaction control system (RCS) requirements were derived from information included in the Spacelab Payload Accommodation Handbook, October 1974, and are representative of flights where minimal orbital maneuvers are required.

2. Cabin leakage was accounted for with atmosphere makeup included for flight durations in excess of seven days.
3. Electrical power demand was assumed at a 7.0 kW total average level utilizing the four 840-kwh Orbiter-supplied (and payload-chargeable) power kits. The breaks in the curves past 7 days reflect the additional payload-chargeable fuel cell reactants and tankage requirements. If solar arrays are used, equivalent power levels would be required. However solar array installation, deployment, retraction in the Orbiter cargo bay would require preliminary design and weight trade analyses.
4. The crew support provisions, leakage rates and RCS propellants are based on the weights defined in Space Shuttle System Payload Accommodations (JSC 0700, Volume XIV, July 1974). These elements were then extrapolated for the reference flight durations. The difference between launch and landing weights are the gases and liquids which go overboard during the flight either through leakage or utilization during the mission.

The weights for the 30-day Spacelabs are compared to the 32-klb planned landing limit in Figure D-8. Subtraction shows net payloads of 7k to nearly 15.0 klb could be launched and landed for orbital durations of 30 days. Beyond 30-days the discretionary weight available for payloads rapidly disappears.

The present Spacelab utilizes fuel cell power from the Orbiter; however, it may be feasible to utilize solar arrays in lieu of additional cryogenic reactants for the fuel cells during orbital operations. Figure D-9 is a comparison between fuel cells and solar array operations as a function of weight for Configuration No. 1 which would be typical. This comparison shows that longer mission durations are possible if solar arrays are utilized, and they allow a greater payload accommodation for periods over 16 days. With the Spacelab, the power required by the Orbiter is 8.3 kW plus 7 kW for the payload, of which 2.9 kW is for the Spacelab and its subsystems and the remaining 4.1 kW for experiments. Using fuel cell kits of 840 kWh, the crossover point for launch weight for a solar array/battery system occurs at approximately 14 days. The cross over point for landing weight occurs at about 16 days.

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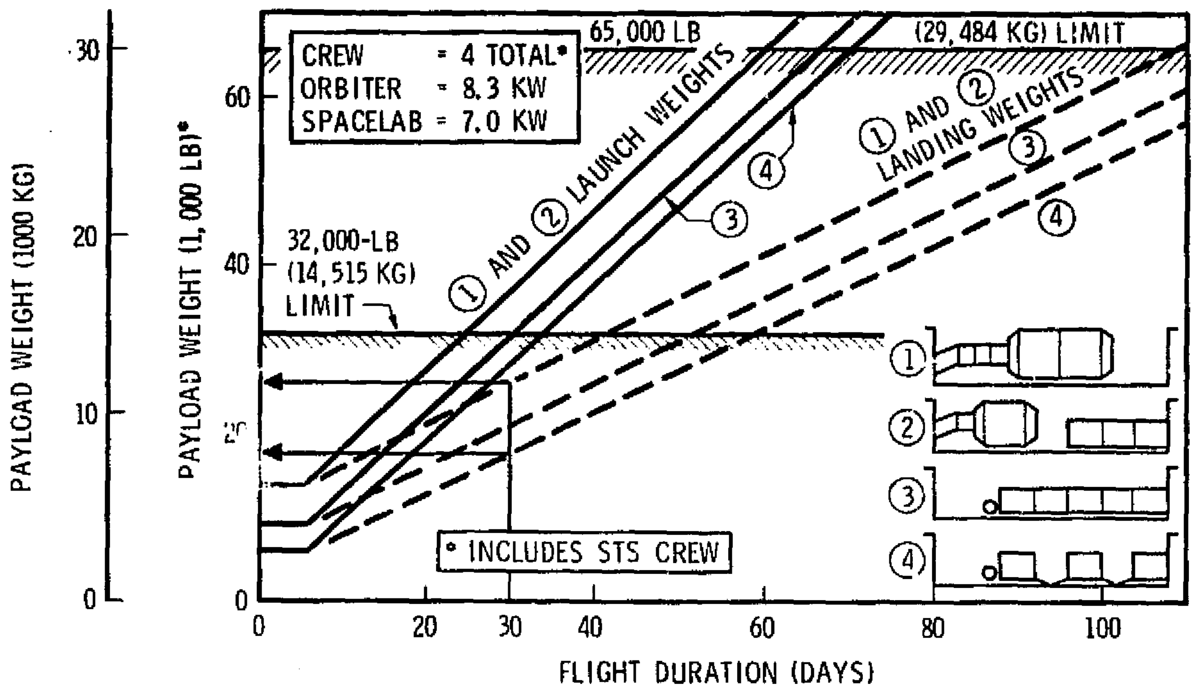

Figure D-8. Attached Spacelab Systems Weights Configuration Summary

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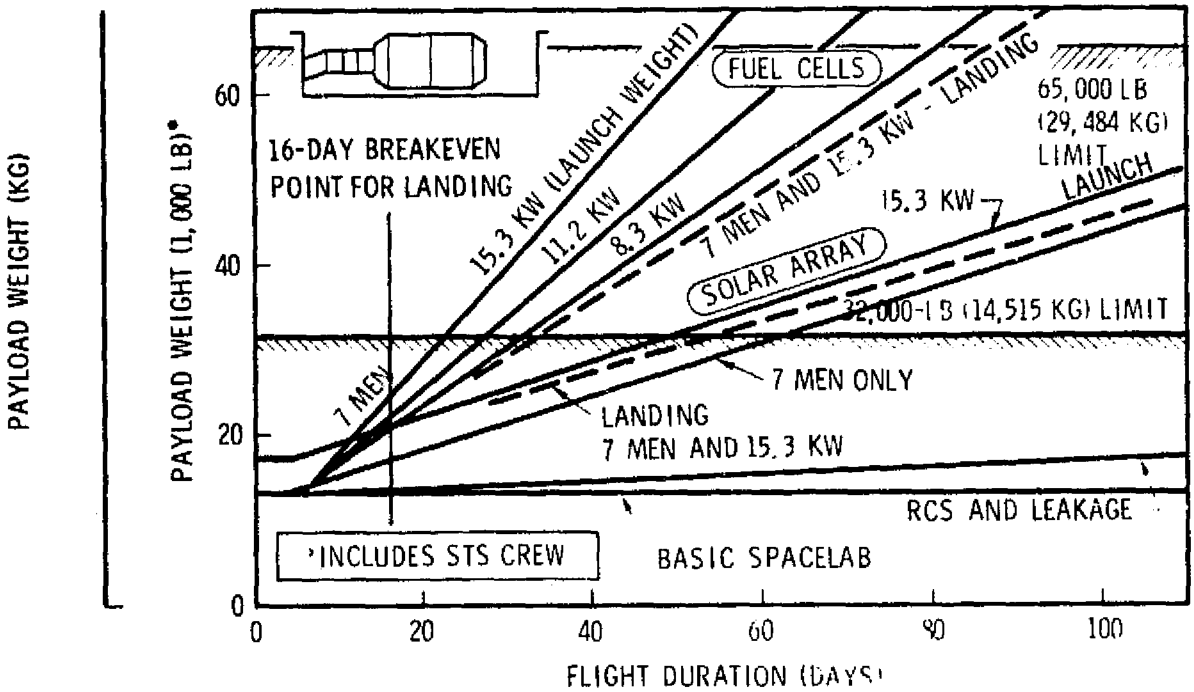

Figure D-9. Attached Spacelab Electrical Power Source Weights Configuration 1

Figure D-10 illustrates crew systems and power weight growth as a function of flight duration for a Spacelab configuration, using the long module and various crew sizes and the corresponding decrease in available payload weight. If a 32 klb landing limit remains as a firm requirement, missions utilizing a crew size of seven (three Shuttle crew and four scientist-astronauts) and 15.3 kW (fuel cells) can be accomplished with a net payload of about 10.0 klb for mission durations of 20 days. This mission would require a 42 klb launch weight, which includes 10.0 klb of consumables (primarily fuel cell cryogenics), which would be expended or jettisoned prior to landing.

The data shown is based upon using the existing Spacelab system (orbiter fuel cells), plotted for crew sizes for four and seven. Solid lines are the launch weights and the dashed lines are landing weights.

Figure D-11 is a plot of the discretionary payload capabilities of the four Spacelab configurations assuming a crew of four as a function of flight duration.

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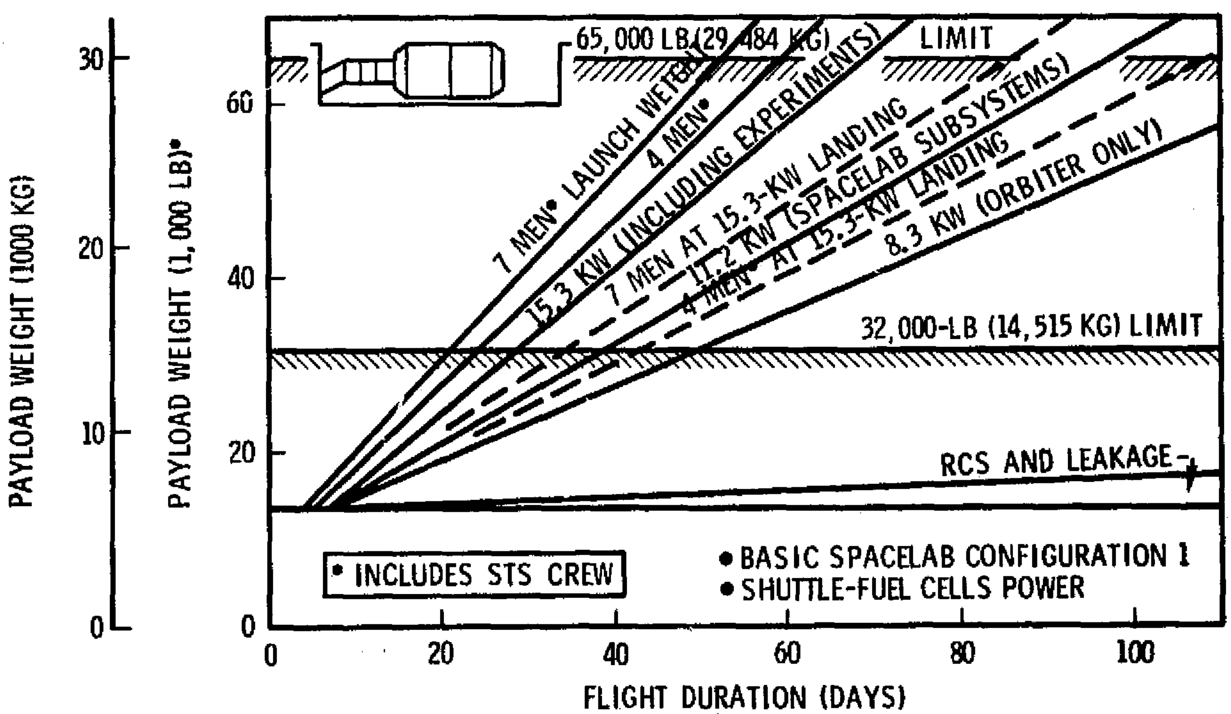


Figure D-10. Attached Spacelab System Weights Crew and Power Variables Configuration 1

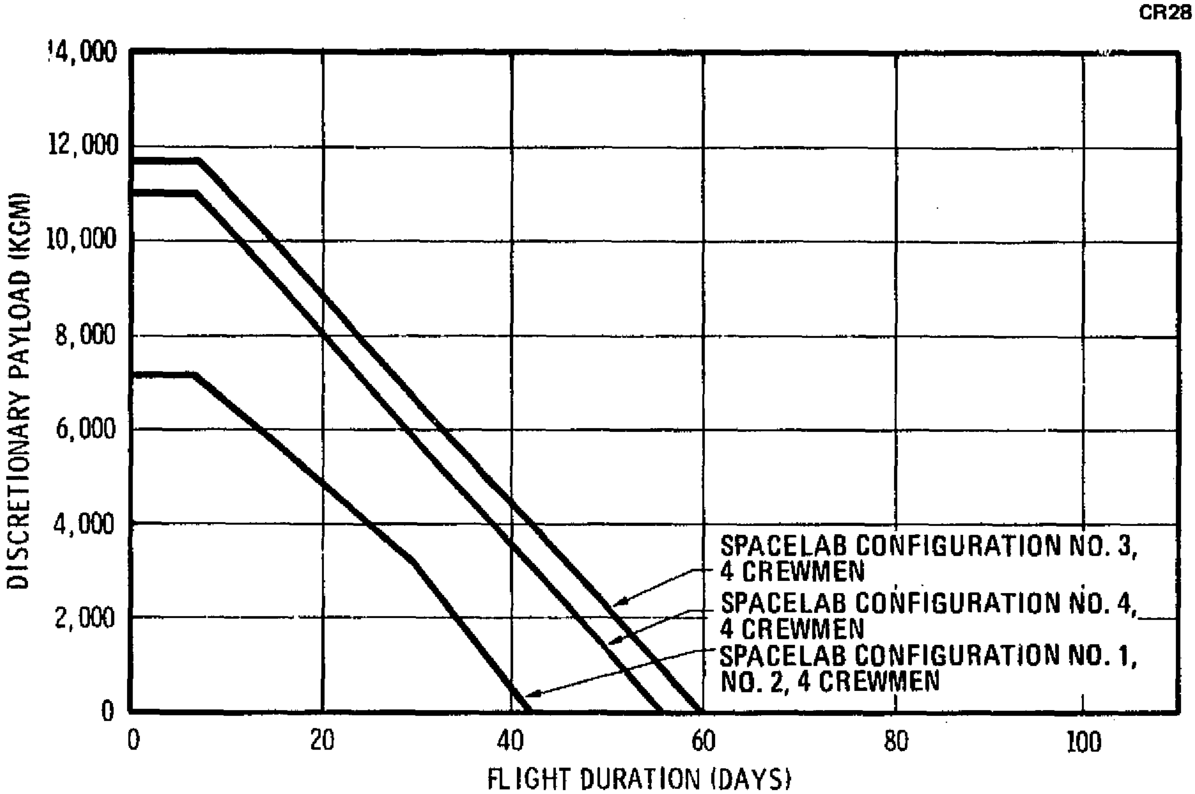


Figure D-11. Extended Spacelab Payload Capabilities — 32,000-lb Takeoff Weight

From the data plotted in Figures D-2 to D-11, it may be seen that all Shuttle attached modes of operation have absolute flight duration limits of about 60 days and practical flight duration limits on the order of around thirty days subject to the variations of desired payload weights and the assumptions under which the flight operations are to be conducted.

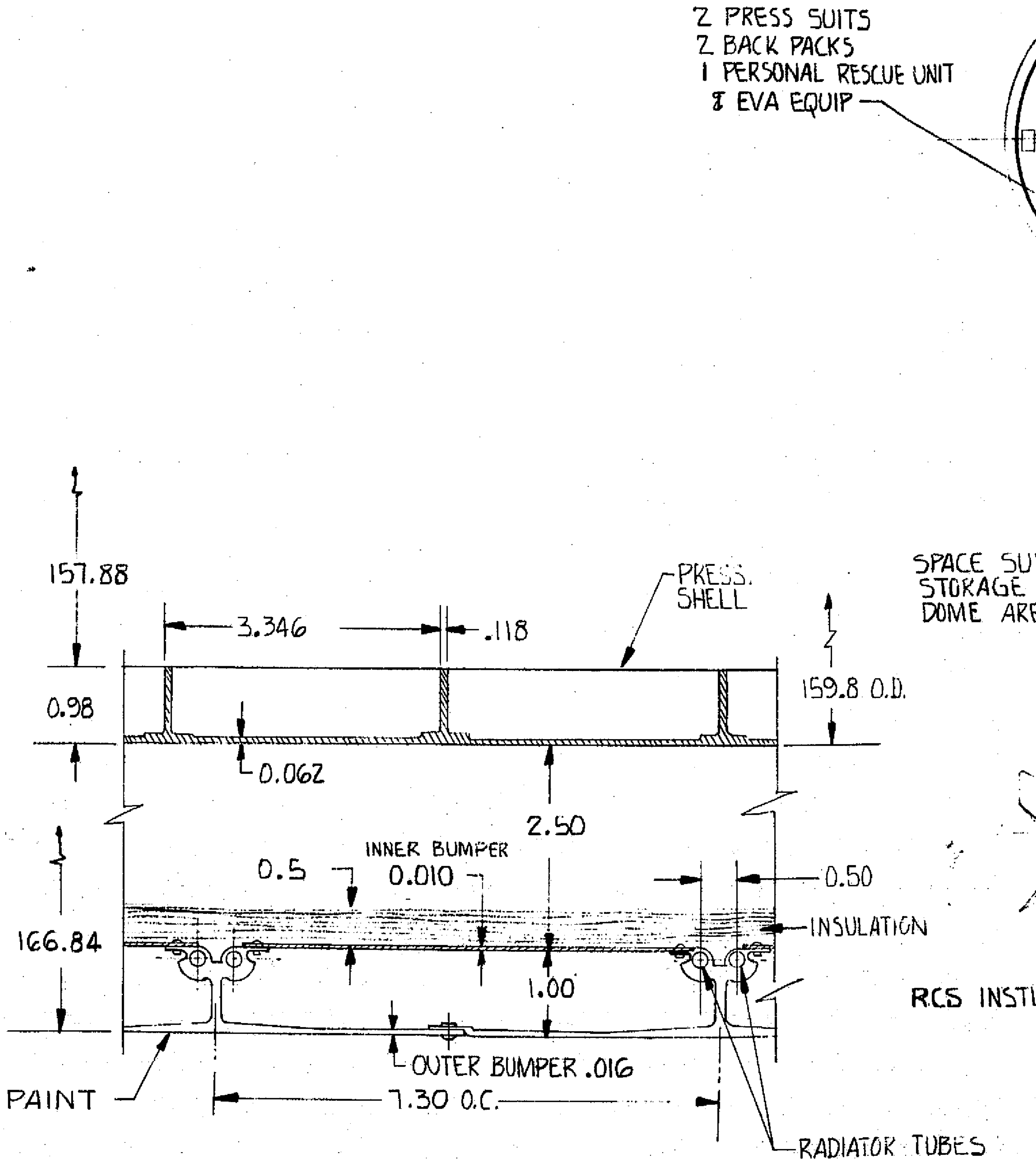
The only way certain payloads could be maintained in orbit for longer periods would be to have at least portions of the system capable of being detached from the orbiter and left in orbit while the orbiter itself, with the 32,000 lbs down payload weight limitation, returns to Earth. This would require the development of self-sustaining modules with station keeping capability which in turn would be essentially free-flying platforms.

For these reasons and because of the limited mission durations possible in the Shuttle attached operational mode and the resulting multiple flight requirement to achieve longer duration missions, a permanent orbital facility appears

to have significant cost and operational advantages ove a short-duration (i. e., 30 to 60 days) Shuttle attached facility. Furthermore, an Orbiter utilized in an extended duration mode is effectively out of service and not available for other concurrent missions during the time period.

A permanently manned facility offers considerable growth potential and when viewed as a modular building block system it can become a logical step leading to larger orbital facilities and missions of broader scope. The permanent orbital facility concept also would minimize interference with other Shuttle traffic and 7-day Spacelab operations by reducing the requirements for multiple Shuttle flights to accomplish a given research program. In fact, over 40 percent of the planned payloads (725 missions) in the NASA Shuttle Traffic Model could benefit from mission durations of greater than seven days if such a manned orbital facility were available.

Accordingly, with NASA concurrence it was decided following the Second Midterm Briefing that the remainder of the study should emphasize the conceptual definition and programmatic evaluation of a permanent orbital facility capable of supporting space activities in low inclination and polar low-Earth orbits.



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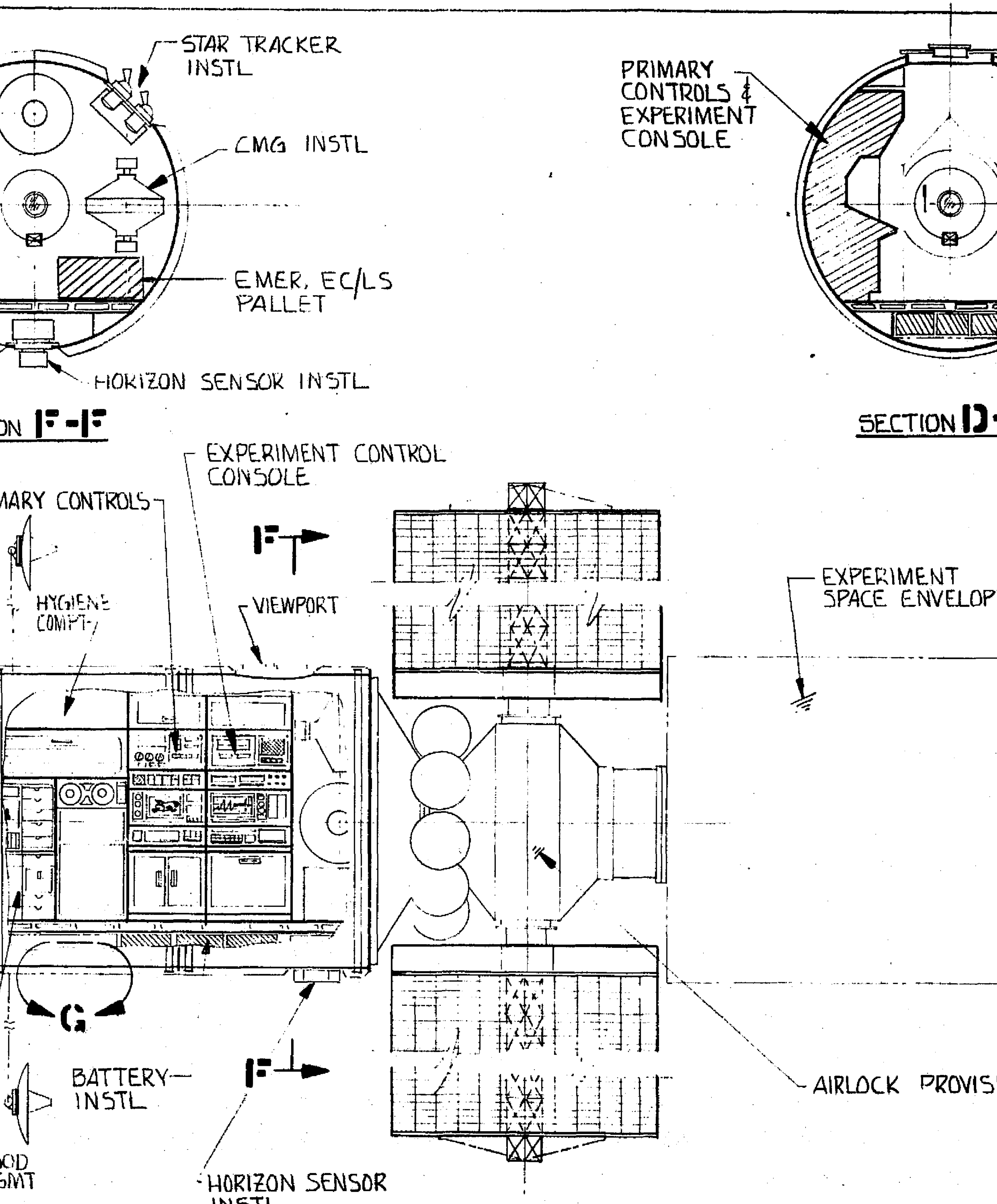

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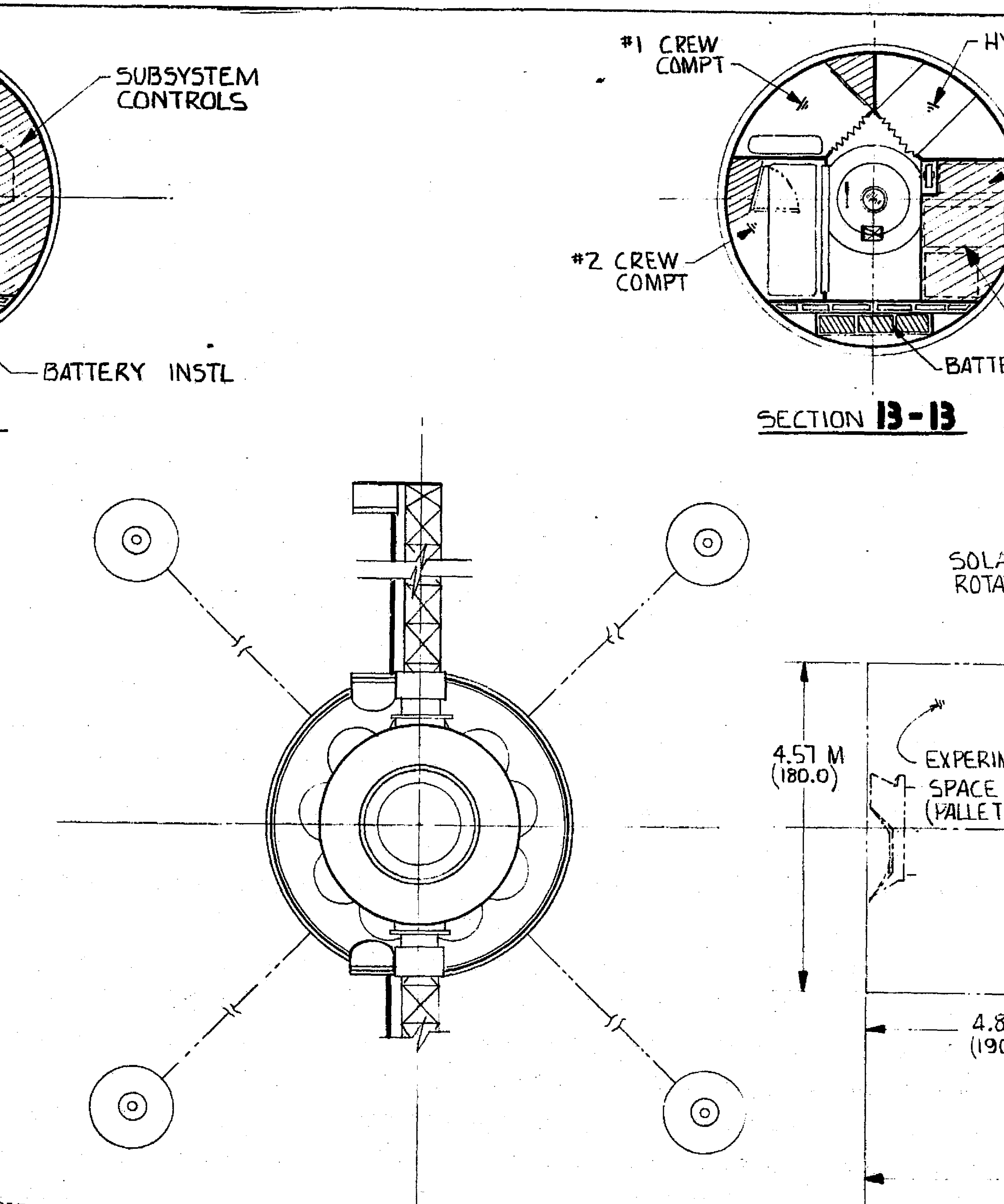

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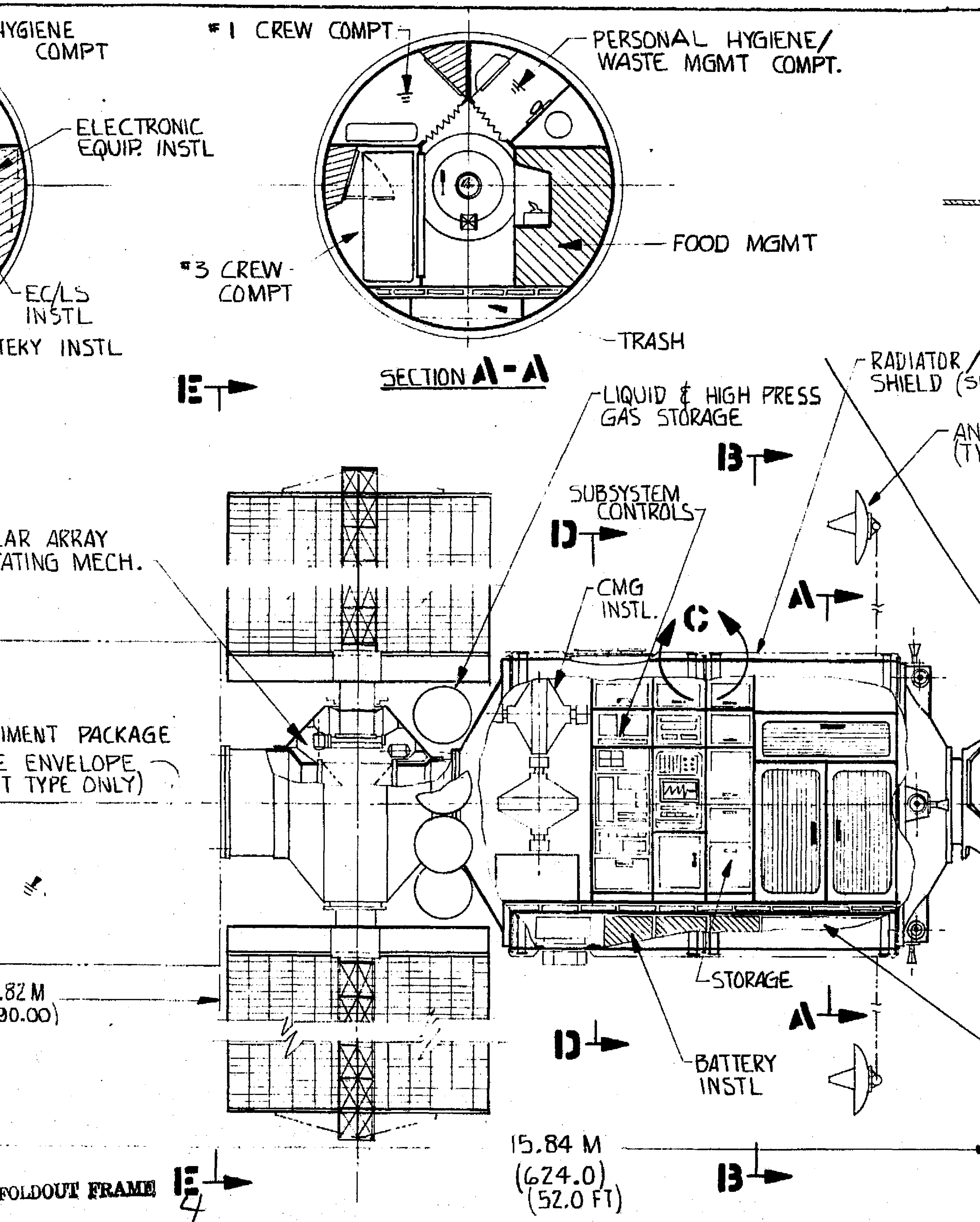

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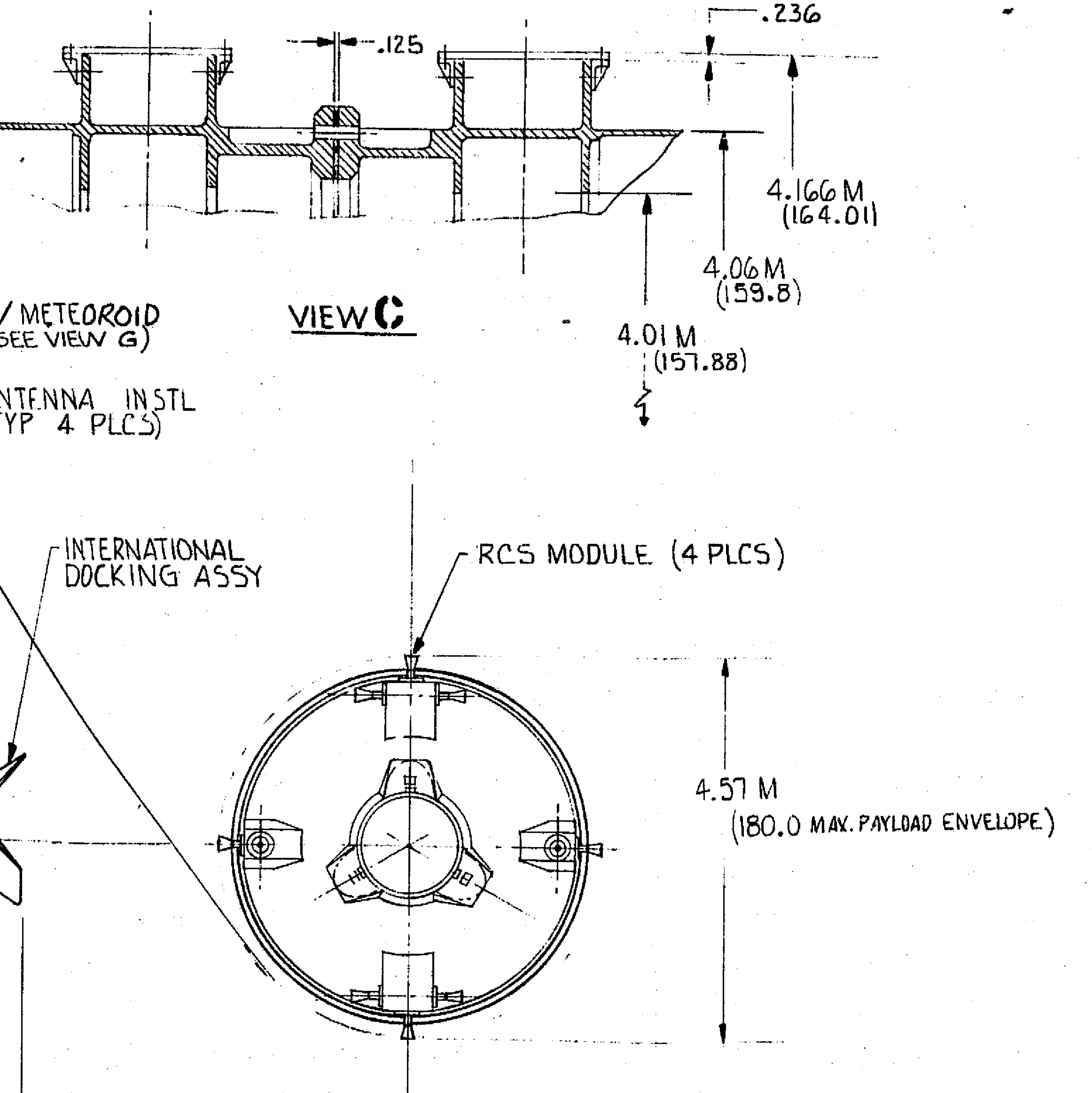

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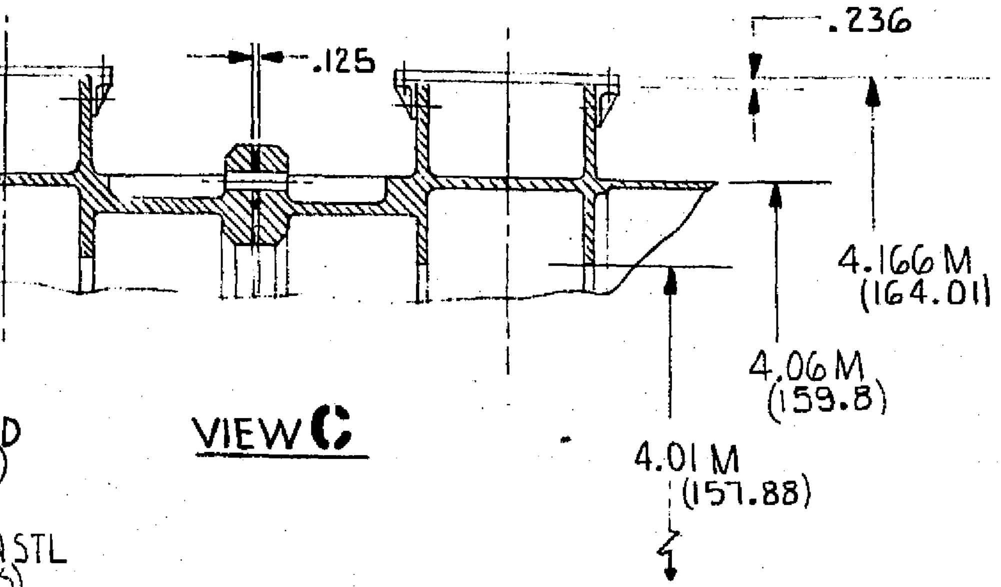

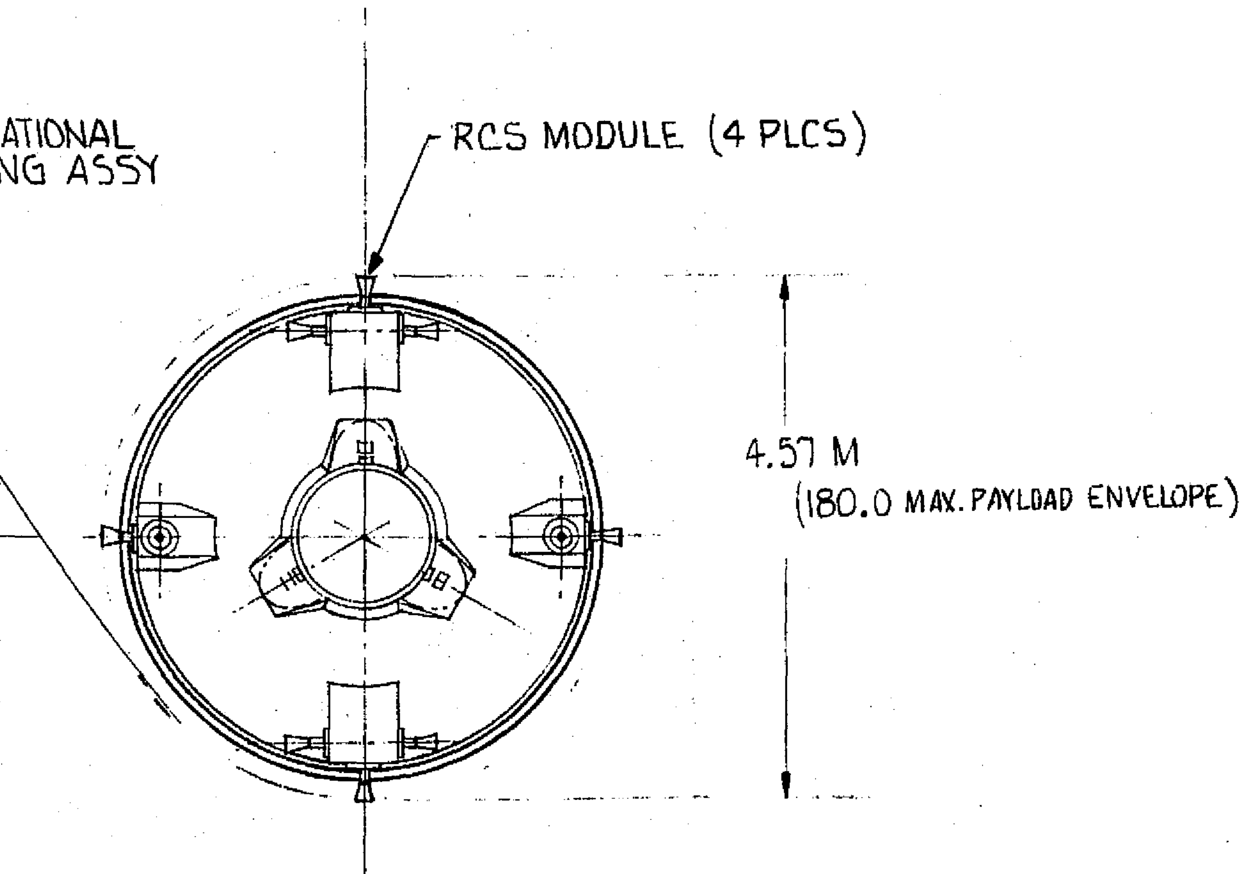

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Appendix E
LIMITED-DURATION CONCEPT (3-MAN MOSC)

Appendix E
LIMITED-DURATION CONCEPT (3-MAN MOSC)

Situations can be anticipated in which a free-flying manned facility may be required for limited durations (to 60 days) to accommodate special events. Accordingly, an alternative MOSC configuration was developed which represented a completely self-contained facility capable of being delivered to orbit by a single launch of the Space transportation system.

This MOSC alternate configuration as shown in Figure E-1* is designed for a 60-day orbital mission and is a single launch-to-orbit facility without orbital resupply capability. The outboard profile and payload accommodations were designed for compatibility with the following Orbiter characteristics: (1) cargo bay envelope, (2) planned landing weight limit, and (3) orbital operations.

The maximum space station length that can be installed in a cargo bay that has the Orbiter docking adapter installed is approximately 52 feet. This length allows a total end clearance of 2 feet. The 3-man module and tunnel are 36.2 feet, which leaves 15.8 feet for the payload pallet. As the limited-duration MOSC must return from orbit at the completion of each mission, it must meet the landing weight limitation of 32,000 pounds.

Experiments requiring laboratory conditions would be located in the free volume of the pressurized module. This places limits upon the weight, volume, and dimensional parameters that can be accommodated. The payload pallet would be attached to the tunnel end of the configuration in order to keep the docking port available for Orbiter docking and to maximize the clearance between the solar arrays and the Orbiter.

*An engineering drawing of the inboard profile appears at the end of this appendix.

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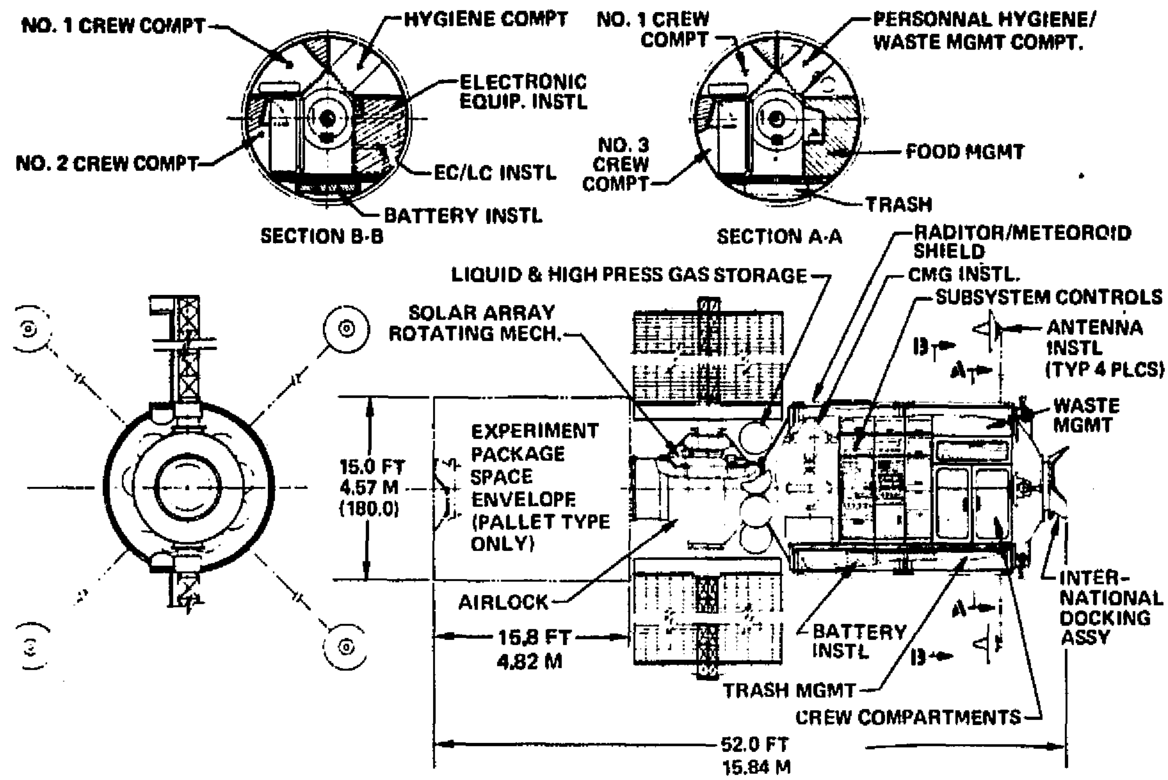

Figure E-1. MOSC 3-Man Limited – Duration Configuration

The module interior has been laid out so that all subsystems and crew facilities are in one pressurized volume. This module consists of two cylindrical segments. Two crew quarters have 80 ft^3 and the third has 100 ft^3 and would nominally be assigned as the commander's quarters. A wardroom could not be included within the limited volume; therefore, the crew quarters and galley area must be used as general purpose facilities. The personal hygiene/waste management area, which is located in the crew quarters area, is allocated 100 ft^3, which appears adequate when compared to Skylab's 126 ft^3. Subsystems equipment is located centrally with payload-oriented equipment located forward toward the solar array turret and payload module.

EVA airlock provisions are provided by utilizing the pressurized volume in the solar array tunnel. Attitude control employs two CMG's and four RCS modules located on the aft conic structure, which correct for missed docking

disturbances. The baseline MOSC RCS functions were divided between the habitability and logistics modules.

The solar array turret is the same configuration used on the baseline, except the international docking assembly interfacing with the payload module has been deleted and a bolted connection substituted.

The overall length of the subsystem/habitability module concept is 36.15 ft (11.02m) which permits the accommodation of a 15.83-ft (4.82m)-long payload for an overall length of 52.5 ft.

The design of the ECLS system for the three-man configuration (see Table E-1) is similar to the baseline subsystem except that expendables have been reduced to a three-man level, the logistics module storage capability has been removed, and the redundancy level in the thermal control subsystem has been reduced. Safety has not been compromised, although emergency stores have been reduced to supply three men for four days; the emergency pallets themselves are the same as those sized to support four men for the baseline. A small additional weight saving is possible due to the off loading of supplies to the three-man level. Although safety levels have not been jeopardized, the probability of mission success has been reduced somewhat by the reduction in redundancy level. A preliminary equipment list is presented in Table E-2.

Assuming that the prime program will be the 4-man baseline system and the limited duration three man facility would be derived from the baseline, all systems are sized for four men although consumables reflect the needs of a three-man crew. Table E-3 shows the changes in ECLS characteristics relative to the baseline. This data shows that weights, volume, and power would be reduced significantly from the baseline. This of course, is essential to make a single-launch, 60-day mission possible.

The total Orbiter launch mass would include the 3-man MOSC (27,489 lbm/ 12,469 kg), the transfer tunnel 2,200 lbm (998 kg), plus the three crewman 1,125 lbm (510 kg) and supporting gear. This coupled with the jettison of normally expended fluids and gases would permit a payload of 1,732 lbm (785 kg) if the return landing mass is limited to 32,000 lbm (14,515 kg).

Table E-1

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM PERFORMANCE REQUIREMENTS SUMMARY

Item	Limited-Duration 3-man MOSC	Baseline 4-man MOSC
Mission Parameters		
No. of Launches	Single	Single or multiple
Resupply period	60 days	90 days
Power concept	Solar cells	Solar cells
Design philosophy	Austere	Low cost and flexible
Redundancy philosophy	Not redundant	Not redundant
Crew size	3	4
Growth goals	Expand to 4 men	Expand to 6 men
Number of compartments	2	2 minimum
Emergency provisions	4 days	4 days
ECLSS Performance Characteristics		
Atmosphere	Air - 14.7 psia	Air - 14.7 psia
Repressurization gas storage	Largest compartment	Largest compartment
Atmosphere temperature	65 to 80°F	65 to 80°F
Atmosphere leakage	3 lb/day/compartment	3 lb/day/compartment
Humidity level - dewpoint	43 to 60°F	43 to 60°F
Metabolic O_2 consumption	1.85 lb/man day	1.85 lb/man day
Carbon dioxide production	2.18 lb/man day	2.18 lb/man day
Metabolic rate	560 Btu/man hr	560 Btu/man hr
Crew potable water intake	6 lb/man day	6 lb/man day
Crew wash water	4 lb/man day	4 lb/man day
Thermal Characteristics		
Heat load	Electrical + crew + chemical	Electrical + crew + chemical
Wall temperature limits	60 to 105°F	60 to 105°F
Vehicle orbital orientation	Any	Any
Thermal capacitance	For orbital fluctuations	For orbital fluctuations

Table E-2 (Page 1 of 2)

3-MAN LIMITED-DURATION MOSC CONFIGURATION – ENVIRONMENTAL CONTROL SYSTEM EQUIPMENT LIST

Equipment Items	Fixed Equipment				Expendables (90 day)		Location
	No. Req'd	Weight (lb)	Volume (ft^3)	Power (watts)	Weight (lb)	Volume (ft^3)	
O_2 and N_2 Storage	5	2025	77.5	0	1075	77.5	CV/LM
Repress Air Storage	1	405	15.5	0	100*	15.5	CV/LM
Oxygen Pressure Regulation	1	20	0.4	2	0	0	CV
Nitrogen Pressure Regulation	2	40	0.8	4	0	0	1 in LM & 1 in SM
Atmosphere Pressure Control	1	28	0.6	24	0	0	SM
Cabin Dump and Relief	2	14	0.4	24	0	0	1 in each module
Airlock Pressure Control	1	7	0.1	0	0	0	HM airlock
PLSS Recharge	1	0.5	0.02	0	0	0	LM
Cabin Fans	2	72	4.4	606	0	0	1 each in HM & SM
CO_2 Control	1	9	5.5	3	802	40	CV/LM
Humidity & Temperature Control	2	70	2.4	36	0	0	1 each in HM & SM
Water Separation	1	11	3.3	44	0	0	SM
Distribution Ducts & Control Valves	Set	120	12.0	0	0	0	All modules
Avionics Fans	2	32	2.2	486	0	0	1 each in HM & SM
Avionics Heat Exchanger	2	92	3.2	6	0	0	1 each in HM & SM
Contamination Monitoring	1	33	1	50	0	0	SM
Fire & Smoke Detection	2	24	0.8	40	0	0	1 each in SM & HM, sensors in LM

*Not normally used

3-MAN LIMITED-DURATION MOSC CONFIGURATION — ENVIRONMENTAL CONTROL SYSTEM EQUIPMENT LIST

	Fixed Equipment				Expendables (90 day)		
Equipment Items	No. Req'd	Weight (lb)	Volume (ft^3)	Power (watts)	Weight (lb)	Volume (ft^3)	Location
Fire Suppression	2	40	1.4	0	0	0	1 each in SM & HM
Water Recovery	2	360	9	43	23	1.4	Redundant units in SM/LM
Water Dispenser	1	15	1	26	0	0	HM
Coolant Water Circulation	1	10	0.3	53	0	0	SM
Radiator Circulation	1	20	1	274	0	0	SM airtight compartment
Interloop Heat Exchanger	1	30	2	0	0	0	SM airtight compartment
Thermal Capacitors	10	275	2.5	0	0	0	SM airtight compartment
Regenerative Heat Exchanger	1	15	1	0	0	0	SM airtight compartment
Crew Prebreathing	3	30	1.5	0	0	0	Airlock Area
Cold Plates	16	135	4.2	0	0	0	4 in SM, 2 in HM & 10 for thermal capacitors
Portable Life Support	3	309	21.3	0	0	0	HM airlock
Emergency Pallets	2			0	0	0	2x4 men for 96 hrs

Table E-3

ECLS CHARACTERISTICS FOR LIMITED DURATION AND AS DELTA'S FROM BASELINE

MOSC Configuration	Fixed Equipment Weight (lb)	Fixed Equipment Volume (ft^3)	90-Day Expendables Power (watts)	90-Day Expendables Weight (lb)	90-Day Expendables Volume (ft^3)
Limited Duration	-751	-26.7	-116	-576	-14.3

This could be improved by reducing mission duration at the rate of 85 lbm (39 kg)/day. Other means are available to increase payload margins by selection of hardware sized directly for this design rather than using equipment from the 4-Man Baseline. Table E-4 is the mass summary with Figure E-2 illustrating the cargo bay installation and Orbiter X_o CG stations for both landing and launch.

A more detailed mass breakdown is presented in Table E-5 and is categorized according to the elements appearing in the MOSC Work Breakdown Structure (WBS).

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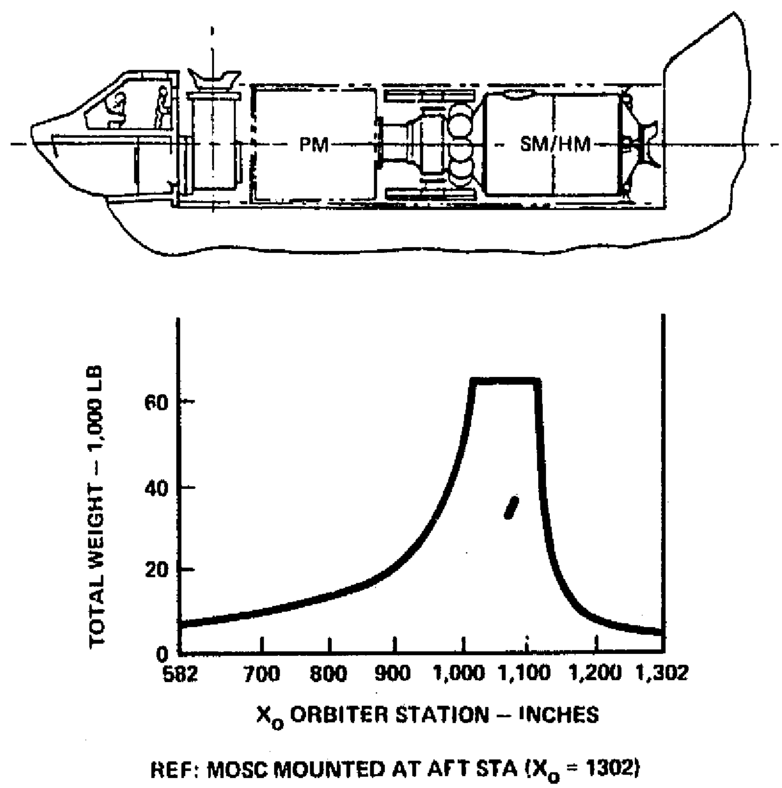

Figure E-2. 3-Man Limited Duration MOSC Vehicle CG vs Orbiter Landing Envelope

Table E-4

3-MAN LIMITED-DURATION MOSC MASS SUMMARY

	Subsystem/Consumables Description	Mass (lb) [kg]
SM/HM	Structure/Mechanical	5,830
	Environmental Protection	575
	Electrical Power	4,665
	Propulsion	344
	Data Management	2,363
	Communication	1,140
	Stability and Control	1,493
	Environmental Control and Life Support	3,515
	Crew Accommodations	3,154
	Subtotal Mass	23,079
	Contingency	2,998
	Inert Mass	26,077
	Residuals/Reserves	866
	In-flight Losses	546
	Launch – Nominal	27,489 [12,469]
	Docking Module	2,200 [998]
	Crew	1,125 [510]
	Launch – Total	30,814 [13,974]
PM	Discretionary Payload	1,732 [785] *
	Landing Total	32,000 [14,517] *

*Inflight Losses Jettisoned

Table E-5

3-MAN MOSC MASS SUMMARY

60-DAY MISSION

WBS	Subsystem/Habitable Module		
03-02 Structure/Mechanical	(5830)		
Primary Structure		3956	
Fwd Conic			467
Fwd End Plate			134
Cly-Basic			1464
Aft End Plate			134
Aft Conic			494
Hatch(s) (3)			258
Fittings (Hard Points)			218
Turret/Tunnel			787
Secondary Structure		961	
Racks/Supports			199
Overhead Structure			154
Floor Supports			172
Floor			436
Subfloor			--
End Closure Floor			--
Airlock			--
Docking		913	
03-10 Environmental Control	(575)		
HPI		319	
Rack Insulation		--	
Radiator Meteoroid		256	
03-05 Electrical Power	(4665)		
Solar Panels and Gimbal Mount		2175	
Batteries		1750	
Power Regulation and Control		210	
Power Conditioning		470	
Power Distribution		60	
03-09 Propulsion	(344)		
N_2 Tanks (3)		234	
Thruster Modules		90	
Distribution Controls		20	
03-07 Data Management	(2363)		
Subsystem		1584	
Data Processing			618
Instrumentation			394
Display and Controls			572
Experiment		469	
Data Processing			226
Display and Controls			243
Wiring		310	

Table E-5 (Page 2 of 5)

3-MAN MOSC MASS SUMMARY

60-DAY MISSION

WBS	Subsystem/Habitable Module			
03-06 Communication	(1140)			
S-Band		334		
Antennas			22	
RF and Signal Processor			312	
Ku-Band		685		
Antennas (Hi-Gain)			525	
RF and Processor			160	
Internal Communication		21		
Wiring		100		
03-08 Guidance and Control	(1493)			
CMGs (3)		1300		
Horizon Sensor		45		
Solar Sensors (2)		10		
Star Sensors (2)		120		
Rate Gyros (3)		3		
Wiring		15		
03-03 Environmental Control and Life Support	(3515)			
Equipment Thermal Control		269		
Cold Plates			135	
Avionics Fan			32	
Plumbing			10	
Heat Exchanger			92	
E. C. Personal		2866		
Atmosphere Supply and Control			1794	
Repressurization O_2 and N_2 Storage Bottles				405
O_2 and N_2 Storage Bottles				1215
Cabin Dump and Relief				14
Pump Down Accumulator				--
Pressure Control				28
Pressure Regulator (N_2 and O_2)				60
PLSS Recharge				--
Fans				72
Atmosphere Reconditioner			651	
Air Temperature and Humidity Control				70
Contaminant Control				33
CO_2 Removal				541
Airlock Pressure Control				7
Catalytic Burner				--
Fire Control			64	
Fire and Smoke Detection				24
Fire Suppression				40
Ducting and Plumbing			47	
96-Hour Pallets (Inerts)			310	

Table E-5 (Page 3 of 5)

3-MAN MOSC MASS SUMMARY

60-DAY MISSION

WBS	Subsystem/Habitable Module			
03-03 (Continued)				
Radiator Thermal Control		380		
Radiator Recirculation			20	
Radiator Control Assy			40	
Interloop Heat Exchangers (2)			30	
Thermal Capacitors			275	
Regenerative Heat Exchanger			15	
03-04 Crew Accommodations	(3154)			
Restraints		133		
Tethers			103	
Stowage Containers				
Sleep				
Zero-G				
ETC				
EVA				
Handrails			30	
Crew Life Support		1899		
Hygiene			391	
Urine Tanks (3)				78
Fecal Tanks (2)				26
Waste Management Support				123
Consumables				147
Sink/Dryer Assy				20
Food Management			994	
Oven, Chiller Water Heater				161
Utensils				91
Food				617
Food Stowage				125
Housekeeping (see Hygiene)			--	
Trash Management			123	
Compactor				80
Cannister				30
Bags and Liner				3
Support				10
Water Management			391	
Water Separation				11
Water Recovery (2)				360
Water Dispenser				15
Initial Water Supply Bottle				5
Cargo Handling		10		
Furnishings		312		

Table E-5 (Page 4 of 5)

3-MAN MOSC MASS SUMMARY

60-DAY MISSION

WBS		Subsystem/Habitable Module		
03-04 Furnishings (Continued)				
Partitions			169	
Doors			24	
Consoles			--	
Floor (see Structure)			--	
Equipment			80	
Tables				17
Desks				48
Bunks				15
Paint			17	
Lighting - Interior			30	
Lighting - Exterior			92	
Docking				32
Orientation				20
Acquisition				40
Personal Gear		383		
Personal Hygiene			6	
Garments			68	
Bedding				
Miscellaneous			309	
Portable Life Support System				309
O_2 Mask				
IVA/EVA Life Support				
IVA Support				
Pressure Suit				
Crew Support		417		
Medical			50	
Recreation/Exercise			143	
Flight Ops Gear			224	
Subtotaled Mass (LBM)	[23079]			
00-00 Contingency		48		
Environmental Protection		115		
Structure/Mechanical	(2998)			
Electrical Power		467		
Propulsion		34		
Data Management		473		
Communication		228		
Guidance and Control		299		
Environmental Control and Life Support		703		
Crew Accommodations		631		
Miscellaneous		--		
Inert Mass (LBM)	[26077]			

Table E-5 (Page 5 of 5)

3-MAN MOSC MASS SUMMARY

60-DAY MISSION

WBS	Subsystem/Habitable Module		
00-00 (Continued)			
Residuals/Reserves	(866)		
Atmosphere		110	
Propellant Trapped		15	
Radiator		22	
Cold Plates		7	
Water		45	
96-Hour Pallet		264	
Metabolic O_2			71
Water			193
Metabolic O_2		403	
Inflight Losses	(546)		
Leakage		300	
Repressurization		100	
Propellant		146	
Total Mass (LBM)	[27489]		

Appendix F
GROWTH CONCEPT (6-MAN MOSC)

Appendix F
GROWTH CONCEPT (6-MAN MOSC)

Situations can be anticipated in which accommodations for manpower beyond that provided by the baseline 4-man MOSC would be required although additional payload related resources of weight, power; etc are not needed. Accordingly, an alternative MOSC configuration was examined which would accommodate a six-man crew.

The definition of the 6-man MOSC growth concept is subject to several variations in the crew accommodations module location and the related core vehicle arrangement. The long (i. e., two cylindrical sections) habitability module matches the 4-man MOSC crew and subsystem requirements very well, with sufficient free volume to accommodate crew activities, e. g., eating, exercising, recreation, etc. The 6-man MOSC configuration, however, virtually eliminates this free volume and therefore most of the physical exercise activities would have to be performed in the crew quarters.

Figure F-1 shows three options for six-man crew habitability accommodations. Option 6-A is a direct extrapolation of the 4-man Baseline internal arrangement. This approach was predicated upon defining a minimum-cost capability with six crewmen. All internal rearrangements to provide facilities for six men during the 90 day mission occur in the habitability module. Equipment previously located adjacent to the crew quarters was relocated to permit installation of the two additional crew quarters. Due to fixed volume availability, the wardroom was removed to provide the required volume available for rearrangement of equipment.

Free volume is limited and may be marginal for the 90-day mission. In this minimum-cost configuration, one waste management/personal hygiene compartment as designed for the Baseline 4-Man MOSC is utilized although the processing equipment and tankage is sized for six men.

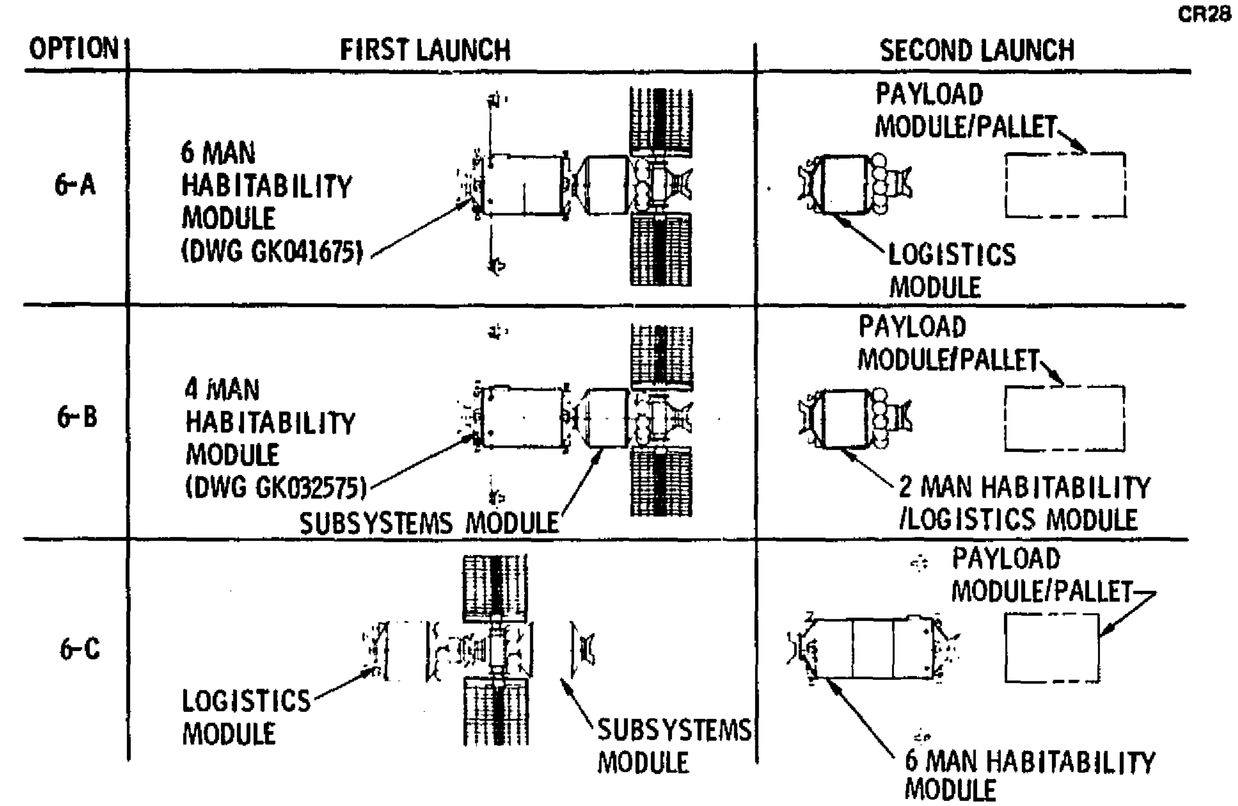

Figure F-1. MOSC 6-Man Core Vehicle Options

An alternative evolutionary path to a six-man basic vehicle would be to reconfigure the logistics module to accommodate two additional crew quarters. In this approach, the core vehicle would have quarters for four crew men, although the required support subsystems (e.g., ECLS) would be sized for six men. This would enable an increase in crew size to be accomplished at any resupply cycle. An illustration of this concept also is shown in Figure F-1, as Option 6-B.

Alternate Option 6-B takes advantage of volume which could be made available to restore the needed free volume. Option 6-B has the disadvantage of returning the two-man crew's quarters with the logistics modules on each resupply cycle.

Option 6-C introduces the large Habitability module with three cylindrical segments. This configuration would provide maximum free volume for the crew, which will be very important for long duration missions. Option 6-C provides an additional clearance envelope for larger solar arrays of increased

width. The smaller payload module is necessary only with the second deployment launch. Subsequent launches would be typical logistics and/or payload modules.

Of the three approaches (Options 6A, 6B and 6C), the favored configuration and the one examined during the study was based on Option 6A. This configuration was believed to reflect a minimum modification to the baseline 4-man concept in terms of module design and subsystems and would therefore represent the lowest cost approach to increasing crew size for specialized missions. Figure F-2 is a conceptual inboard profile of this approach.*

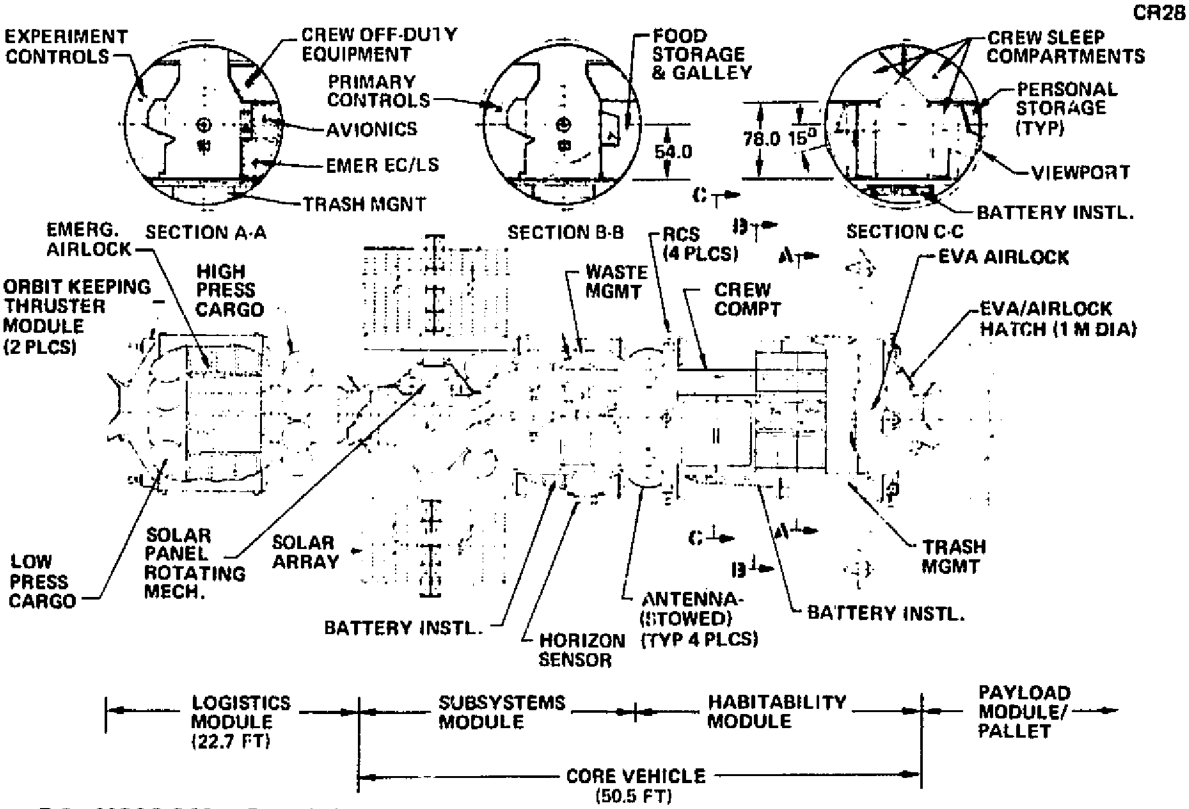

Figure F-2. MOSC 6-Man Growth Configuration

The recommended six-man ECLS capability (See Table F-1) included fully redundant subsystems. Dual atmospheric pressure and composition controls are provided, but not atmospheric gas storage. However, the storage tanks are arranged in two banks installed in a single plane to preclude inadvertent loss of the entire supply. To meet the needs of the additional crewmen, the

*An engineering drawing of this inboard profile appears at the end of this Appendix.

Table F-1

ENVIRONMENTAL CONTROL/LIFE SUPPORT SUBSYSTEM PERFORMANCE REQUIREMENTS SUMMARY

Item	Baseline 4-man MOSC	Growth 6-man MOSC
Mission Parameters		
No. of Launches	Single or multiple	Single or multiple
Resupply period	90 days	90 days
Power concept	Solar cells	Solar cells
Design philosophy	Low cost and flexible	Flexible - excess subsystem capacity
Redundancy philosophy	Not redundant	Fully redundant
Crew size	4	6
Growth goals	Expand to 6 men	Expand to 12 to 24 men
Number of compartments	2 minimum	2 minimum
Emergency provisions	4 days	4 days
EC/LSS Performance Characteristics		
Atmosphere	Air -14.7 psia	Air -14.7 psia
Repressurization gas storage	Largest compartment	Largest compartment
Atmosphere temperature	65 to 80°F	65 to 80°F
Atmosphere leakage	3 lbs/day/compartment	3 lbs/day/compartment
Humidity level - dewpoint	43 to 60°F	43 to 60°F
Metabolic O_2 consumption	1.85 lb/man day	1.85 lb/man day
Carbon dioxide production	2.18 lb/man day	2.18 lb/man day
Metabolic rate	560 Btu/man hr	560 Btu/man hr
Crew potable water intake	6 lbs/man day	6 lbs/man day
Crew wash water	4 lbs/man day	4 lbs/man day
Thermal Characteristics		
Heat load	Electrical + crew + chemical	Electrical + crew + chemical
Wall temperature limits	60 to 105°F	60 to 105°F
Vehicle orbital orientation	Any	Any
Thermal capacitance	For orbital fluctuations	For orbital fluctuations

Table F-2 (Page 1 of 2)

6-MAN GROWTH MOSC ENVIRONMENTAL CONTROL SYSTEM EQUIPMENT LIST

Equipment Items	Fixed Equipment				Expendables (90 day)		Location
	No. Req'd	Weight (lb)	Volume (ft^3)	Power (watts)	Weight (lb)	Volume (ft^3)	
O_2 and N_2 Storage	6	2,585	100	0	1,616	100.	SM/LM
Repress Air Storage	2	810	31	0	400*	31.	SM, 2 large mod. /LM
Oxygen Pressure Regulation	2	40	0.8	4	0	0	LM, dual gas supply
Nitrogen Pressure Regulation	3	60	1.2	6	0	0	1 in LM & 1 in SM dual gas supply
Atmosphere Pressure Control	2	56	1.2	48	0	0	SM
Cabin Dump and Relief		20	0.5	36	0	0	1 in each module
Airlock Pressure Control	1	7	0.1	0	0	0	HM airlock
PLSS Recharge	1	0.5	0.02	0	0	0	LM
Cabin Fans	2	72	4.4	606	0	0	1 each in HM & SM
CO_2 Control	2	18	11.0	6	1,604	80	SM/LM
Humidity & Temperature Control	2	70	2.4	36	0	0	1 each in HM & SM
Water Separation	2	22	6.6	88	0	0	SM
Distribution Ducts & Control Valves	Set	137	15	0	0	0	All modules
Avionics Fans	2	32	2.2	486	0	0	1 each in HM & SM
Avionics Heat Exchanger	2	92	3.2	6	0	0	1 each in HM & SM
Contamination Monitoring	2	66	1	100	0	0	SM
Fire & Smoke Detection	2	24	0.8	40	0	0	1 each in SM & HM, sensors in LM

*Not normally used

Table F-2 (Page 2 of 2)

6-MAN GROWTH MOSC ENVIRONMENTAL CONTROL SYSTEM EQUIPMENT LIST

Equipment Items	Fixed Equipment				Expendables (90 day)		Location
	No. Req'd	Weight (lb)	Volume (ft^3)	Power (watts)	Weight (lb)	Volume (ft^3)	
Fire Suppression	2	60	1.8	0	0	0	1 each in SM & HM improved
Water Recovery	2	400	10	86	47	2.7	Redundant units in SM/LM
Catalytic Burner	2	160	8	180	40	1.8	SM/LM
Water Dispenser	2	30	2	39	0	0	HM
Coolant Water Circulation	2	20	0.6	53	0	0	SM
Radiator Circulation	2	40	1	274	0	0	SM airtight compartment
Interloop Heat Exchanger	2	60	4	0	0	0	SM airtight compartment
Thermal Capacitors	10	275	2.5	0	0	0	SM airtight compartment
Regenerative Heat Exchanger	2	30	2	0	0	0	SM airtight compartment
Crew Prebreathing	6	60	2.5	0	0	0	Airlock Area
Cold Plates	16	135	4.2	0	0	0	4 in SM, 2 in HM & 10 for thermal capacitors
Portable Life Support	6	618	43	0	0	0	HM airlock
Emergency Pallets	2	1,400	13	0	0	0	2x6 men for 96 hrs

growth configuration will have higher weight, volume, and power requirements than the baseline. It is also anticipated that additional radiators will be located on the experiment or logistics module surfaces to accommodate the higher vehicle power and heat dissipation requirements caused by the two additional crewmen.

Although an oxygen recovery subsystem was not assumed for the growth configuration, serious consideration should be given to this option. The larger crew sizes, especially up to 12 men, would make oxygen recovery an attractive feature. The preliminary ECLS equipment list is presented in Table F-2.

The growth characteristics of the six man ECLS system as compared to the four man baseline are summarized in Table F-3.

As noted, the 6-Man Growth MOSC configuration is similar to the baseline except for additional crew provisions and crew expendables, plus added capability in data management for increased payload support. The launch mass would be 34,932 lbm (15,845 kg) on the first flight plus the Docking Module which would be a total of 37,132 lbm (16,839 kg). This mass would reduce to 36,664 lbm (16,527 kg) for landing if only normally expended gases and fluids were vented overboard. This is over the 32,000 lbm (14,515 kg) Orbiter-imposed landing limit but this configuration has over 7,000 lbm (3,175 kg) of logistic options (Tables F-4 and F-5) which could be shifted to other modules on other launches if the 32,000 lbm figure remains firm. Since the nominal mission duration is five years or greater, this would not seem to be a limiting factor. The second launch configuration is about 2,400 lbm (1,089 kg) more than the Baseline for a total launch mass of 26,817 lbm (12,164 kg) exclusive of the crew and the Docking Module. Table F-5 summarizes the mass distribution. Figure F-3 illustrates cargo bay installation and Orbiter X_o CG stations for both landing and launch.

A more detailed mass breakdown is presented in Table F-6 and is categorized according to the elements appearing in the MOSC Work Breakdown Structure.

Table F-3

ECLS CHARACTERISTICS FOR GROWTH VERSION
AS DELTA'S FROM BASELINE

	Fixed Equipment		90-Day Expendables		
MOSC Configuration	Weight (lb)	Volume (ft^3)	Power (watts)	Weight (lb)	Volume (ft^3)
Growth	+1937	+78	+257	+1131	+66.8

Table F-4

SIX-MAN GROWTH MOSC MASS SUMMARY

	Mass (lb) kg			
	First Launch - Core Vehicle		Second Launch - 90-Day Logistic	
Subsystem/Consumables Description	Subsystem Module	Habitability Module	Logistic Module	Payload Module
Structure/Mechanical	4,279	5,496	4,977	4,762
Environmental Protection	323	575	195	489
Electrical Power	4,465	1,380	30	30
Propulsion	169	103	1,190	--
Data Management	1,532	1,409	212	798
Communication	323	826	86	17
Stability and Control	2,146	--	--	--
Environmental Control and Life Support	1,916	908	4,351	144
Crew Accommodations	967	2,877	3,525	169
Subtotal	(16,120)	(13,574)	(14,566)	(6,409)
Contingency	1,930	1,576	2,153	641
Inert Mass	(18,050)	(15,150)	(16,719)	(7,050)
Residuals/Reserves	144	1,120	1,363	227
Inflight Losses	468	--	1,458	--
Module Total	18,662 8,466	16,270 7,380	19,540 8,864	7,277 3,301
Launch - Nominal	34,932 15,845		26,817 12,164	
Decking Module	2,200 998		2,200 998	
Crew/Equipment	--		2,250 1,020	
Launch - Total	37,132 16,839		31,267 14,180	
Discretionary Payload	--		2,191 994 *	
Landing - Total	36,664 16,627 *		32,000 14,512 *	

*Weight of items which can be shifted to an alternate launch

Table F-5

SIX-MAN GROWTH MOSC MASS SUMMARY FOR OPTIONAL LOGISTICS DELIVERIES

Subsystem/Consumables Description	First Launch: Subsystem Module Basic	First Launch: Subsystem Module Logistic* Options	First Launch: Habitability Module Basic	First Launch: Habitability Module Logistic* Options	Second Launch 90-Day Logistic: Logistic Module Basic	Second Launch 90-Day Logistic: Logistic Module Cargo	Second Launch 90-Day Logistic: Payload Module
Structure/Mechanical	4279	--	5496	--	4977	--	4762
Environmental Protection	323	--	575	--	195	--	489
Electrical Power	3625	840	540	840	30	--	30
Propulsion	169	--	103	--	20	1170	--
Data Management	1532	--	1409	--	212	--	798
Communication	323	--	826	--	86	--	17
Guidance and Control	196	1950	--	--	--	--	--
Environmental Control and Life Support	1916	--	908	--	149	4202	144
Crew Accommodations	834	133	686	2191	152	3373	169
Subtotal	(13197) 5987	(2923) 1326	(10543) 4782	(3031) 1375	(5821) 2641	(8745) 3967	(6409) 2907
Contingency	1429	501	1054	522	582	1571	641
Inert Mass	(14626) 6635	(3424) 1553	(11597) 5261	(3553) 1612	(6403) 2904	(10316) 4679	(7050) 3198
Residuals/Reserves	144	--	1030	90	92	1271	227
Inflight Losses	468	--	--	--	--	1458	--
TOTAL MASS	(15238) 6912	(3424) 1553	(12627) 5278	(3643) 1653 *	(6495) 2946	(13045) 5917	(7277) 3301
Module Total Mass (lb) kg	18662 8466		16270 7380		19540 8864		7277 3301
Total Launch Mass with Options	34932 15846				26817 12164		
Total Launch Mass Without Options	27865 12640				33884 15370		

*Weight of items which can be shifted to an alternate launch

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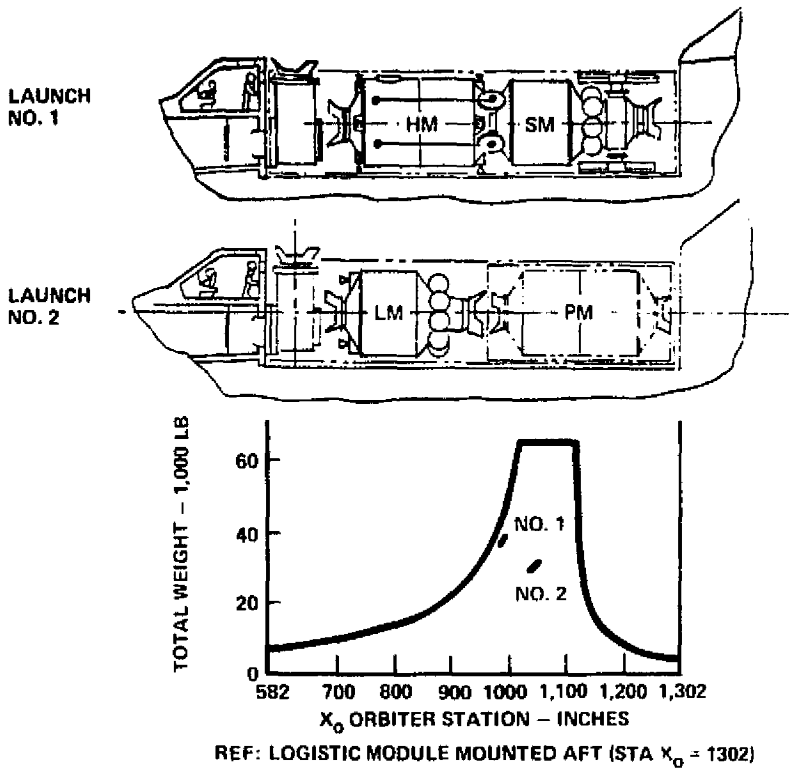

Figure F-3. 6-Man Growth Vehicle CG vs Orbiter Landing Envelope

Table F-6

MOSC SIX-MAN DETAIL MASS SUMMARY 90-DAY LOGISTIC CY

WBS		Subsystem Module (SM)	SM Logistic Options	Habitable Module (HM)	HM Lo
03-02	Structure/Mechanical	(4279)	( )	(5496)	( )
	Primary Structure	2886	----	2935	
	Fwd Conic	467		467	
	Fwd End Plate	134		----	
	Cly-Basic	732		1464	
	Aft End Plate	134		134	
	Aft Conic	494		494	
	Hatch/s	172		258	
	Fittings (Hard Points)	100		118	
	Turret/Tunnel	653		----	
	Secondary Structure	480	----	1648	
	Racks/Supports	99		199	
	Overhead Structure	77		154	
	Floor Supports	86		172	
	Floor	218		436	
	Subfloor	----		----	
	End Closure Floor	----		----	
	Airlock	----		687	
	Docking	913	----	913	
03-10	Environmental Control	(323)	( )	(575)	( )
	HPI	195		319	
	Rack Insulation	----		----	
	Radiator/Meteoroid	128		256	
03-05	Electrical Power	(3625)	(840)	(540)	(840)
	Solar Panels & Gimbal Mount	2375	----	----	
	Batteries	420	840	420	
	Power Regulation & Control	300	----	----	
	Power Conditioning	470	----	90	
	Power Distribution	60	----	30	
03-09	Propulsion	(169)	( )	(103)	( )
	N_2 Tanks	156		----	
	Thrustor Modules	----		90	
	Distribution/Controls	13		13	
03-07	Data Management	(1532)	( )	(1409)	( )
	Subsystem	1326		318	
	Data Processing	558		60	
	Instrumentation	262		132	
	Display & Controls	506		126	
	Experiment	----		766	
	Data Processing	----		476	
	Display & Controls	----		290	
	Wiring	206		325	

*Increase over Baseline reflects additional capability provided for 2 additional crewmen.

FOLDOUT FRAME)

Table F-6

-MAN DETAIL MASS SUMMARY 90-DAY LOGISTIC CYCLE

gistic Options	Habitable Module (HM)	HM Logistic Options	Logistic Module	LM Cargo	Payload Module
	(5496)	( )	(4977)	( )	(4762)
----	2935	----	2571	----	2251
	467		467		467
	----		134		134
	1464		732		732
	134		134		134
	494		494		494
	258		172		172
	118		218		118
	----		220		----
----	1648	----	580	----	685
	199		199		----
	154		77		77
	172		86		172
	436		218		436
	----		----		----
	----		----		----
	687		----		----
----	913	----	1826	----	1826
	(575)	( )	(195)	( )	(489)
	319		195		319
	----		----		----
	256		----		170
	(540)	(840)	(30)	( )	(30)
----	----		----	----	----
840	420	840	----	----	----
----	----	----	----	----	----
----	90	----	----	----	----
----	30	----	30	----	30
	(103)	( )	(20)	(1170)	( )
	----		----	1170	
	90		----	----	
	13		20	----	
	(1409)	( )	(212)	( )	(798) *
	318	----	132		----
	60	----	----		----
	132	----	132		----
	126	----	----		----
	766	----	----		546
	476	----	----		231
	290	----	----		315
	325	----	80		252

FOLDOUT FRAME 2

Table F-6

WBS		Subsystem Module (SM)	SM Logistic Options	Habitable Module (HM)	HM Logistic Options
03.04	Crew Accommodations	(834)	(133)	(686)	(2191)
	Restraints	20	68	30	138
	Tethers	----	68	----	138
	Stowage Containers				
	Sleep				
	Zero G				
	EIC				
	EVA				
	Handrails	20	----	30	----
	Crew Life Support	565	65	201	201
	Hygiene	143	65	----	----
	Urine Tanks (5)	----	39	----	----
	Fecal Tanks (4)	----	26	----	----
	Waste Management Supt.	123	----	----	----
	Consumables	----	----	----	----
	Sink/Dryer Assy	20	----	----	----
	Food Management	----	----	161	181
	Oven, Chiller	----		----	----
	Water Heater	----		161	----
	Utensils	----		----	----
	Food	----		----	14[illegible]
	Food Stowage	----		----	3[illegible]
	Housekeeping (see Hygiene)	----	----	----	----
	Trash Management	----	----	10	----
	Compactor	----		----	----
	Cannister	----		----	----
	Bags & Liner	----		----	----
	Support	----		10	----
	Water Management	422	----	30	20 ----
	Water Separation	22		----	----
	Water Recovery (2)	400		----	----
	Water Dispenser	----		30	----
	Initial Water Supply Bottle	----		----	2[illegible]
	Cargo Handling	10	----	10	----
	Furnishings	239	----	445	----
	Partitions	77		154 *	----
	Doors	6		30	
	Consoles	----		----	
	Floor (see Structure)	----		----	
	Equipment	16		122	
	Tables	----		17	
	Desks	16		80	
	Bunks	----		25	
	Paint	10		17	
	Lighting - Interior	10		30	
	Lighting - Exterior	120		92	
	Docking	80		32	
	Orientation	30		20	
	Acquisition	30		40	
	Personal Gear	----	----	----	840
	Personal Hygiene				18
	Garments				204
	Bedding				----
	Miscellaneous				618
	Portable Life Supt. Sys.				61[illegible]
	O2 Mask				----
	IVA/EVA Life Support				----
	IVA Support				----
	Pressure Suit				----

OUT FRAME

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*Removal of wardroom and replacement with two additional crewquarters approximate same weight as in Baseline allowance.

Logistic Options	Logistic Module	LM Cargo	Payload Module
)	(152)	(3373)	(169)
138	20	----	20
138	----		----
----	20		20
201	----	3373	----
----	----	649	----
----	----	130	
----	----	52	
----	----	----	
----	----	441	
----	----	----	
181	----	2495	----
----	----	----	
----	----	----	
----	----	273	
144	----	1852	
37	----	370	
----	----	----	----
----	----	182	----
----	----	83	
----	----	90	
----	----	9	
----	----	----	
20 ----	----	47	----
----	----	----	
----	----	47	
----	----	----	
20	----	----	
----	20	----	10
----	112	----	139
----	----		

	10		
	10		
	92		
	32		
	20		
	40		
840	----	----	----
18			
204			

618			
618			

FOLDOUT FRAME 2

Table F-6

WBS		Subsystem Module (SM)	SM Logistic Options	Habitable Module (HM)	HM Logistic Options
03-06	Communication	(323)	( )	(826)	( )
	S-Band	274		60	
	Antennas	22		----	
	RF & Signal Processor	252		60	
	Ku-Band	----		685	
	Antennas (Hi-Gain)	----		525	
	RF & Processor	----		160	
	Internal Communication	9		20	
	Wiring	40		61	
03-08	**Stabilization & Control**	(196)	(1950)	( )	( )
	CMGs (3)	----	1950	----	
	Horizon Sensor	45	----	----	----
	Solar Sensors (2)	10	----	----	----
	Star Sensors (2)	120	----	----	----
	Rate Gyros (3)	5	----	----	----
	Wiring	16	----	----	----
03-03	Environmental Control & Life Support	(1916)	( )	(908)	( )
	Equipment Thermal Control	192	----	91	----
	Cold Plates	118		17	
	Avionics Fan	16		16	
	Plumbing	10		10	
	Heat Exchanger	48		48	
	E.C. Personal	1299	----	797	----
	Atmosphere Supply & Cont.	949		43	
	Repressurization O_2 & N_2 Bottles	810		----	
	O_2 & N_2 Storage Bottles	----		----	
	Cabin Dump & Relief	7		7	
	Pump Down Accumulator	----		----	
	Pressure Control	56		----	
	Pressure Regulator (N_2 & O_2)	40		----	
	PLSS Recharge	----		----	
	Fans	36		36	
	Atmosphere Reconditioner	261		42	
	Air Temp. & Humid. Cont.	35		35	
	Contaminant Control	66		----	
	CO_2 Removal	----		----	
	Airlock Pressure Control	----		7	
	Catalytic Burner	160		----	
	Fire Control	42		42	
	Fire & Smoke Detection	12		12	
	Fire Suppression	30		30	
	Ducting & Plumbing	47		50	
	96-Hour Pallets (Inerts)	----		620	
	Radiator Thermal Control	425	----	20	----
	Radiator Recirculation	20		20	
	Radiator Control Assy	40		----	
	Interloop Heat Exchangers (2)	60		----	
	Thermal Capacitors	275		----	
	Regenerative Heat Exchanger	30		----	

DOUT FRAME

Table F-6

Habitable Module (HM)	HM Logistic Options	Logistic Module	LM Cargo	Payload Module
(826)	( )	(86)	( )	(17)
60		52		....
....		22		....
60		30		
685		....		....
525		....		....
160		....		....
20		4		6
61		30		11
( )	( )	( )	( )	( )
....		....		....
....	....	....		....
....	....	....		....
....	....	....		....
....	....	....		....
....	....	....		....
(908)	( )	(149)	(4202)	(144)
91	....	....	....	30
17		....	....	....
16		....	....	....
10		....	....	....
48		....	....	....
797	....	149	4202	114
43		67	2580	7
....		....	....	....
....		....	2580	....
7		7	....	7
....		....	....	....
....		....	....	....
....		60	....	....
....		....	....	....
36		....	....	....
42		....	1622	35
35		....	....	35
....		....	....	....
....		....	1622	....
7		....	....	....
....		....	....	....
42		42	....	32
12		12		12
30		30		20
50		40	....	40
620		....	....	....
20	....	....	....	....
20		....		....
....		....		....
....		....		....
....		....		....
....		....		....

FOLDOUT FRAME

2

Table F-6

WBS		Subsystem Module (SM)	SM Logistic Options	Habitable Module (HM)	HM Logistic Options
03-04	Crew Accommodations (Cont)				
(cont)	Crew Support	----	----	----	1012
	Medical				150
	Recreation/Exercise				190
	Flight Ops Gear				672
	Subtotaled Mass (LBM)	[13197]	[2923]	[10543]	[3031]
00-00	Contingency	(1429)	(501)	(1054)	(522)
	Structure/Mechanical	24	----	82	----
	Environmental Protection	65	----	115	----
	Electrical Power	363	84	54	84
	Propulsion	17	----	10	----
	Data Management	306	----	282	----
	Communication	65	----	164	----
	Guidance & Control	39	390	----	----
	Environmental Control & Life Supt.	383	----	178	----
	Crew Accommodations	167	27	137	438
	Misc	----	----	32	----
	Inert Mass (LBM)	[14626]	[3424]	[11597]	[3553]
	Residuals/Reserves	(144)	( )	(1030)	(90)
	Atmosphere	110	----	184	----
	Propellant Trapped	5	----	----	----
	Radiator	22	----	43	----
	Cold Plates	7	----	2	----
	Water	----	----	----	90
	96 Hour Pallet	----	----	801	----
	Metabolic O_2	----		222	
	Water	----		579	
	Metabolic O_2				
	Inflight Losses	(468)	( )	( )	( )
	Leakage	18			
	Repressurization	400			
	Propellant	50			
	Total Mass (LBM)	[15238]	[3424]	[12627]	[3643]

OUT FRAME)

Logistic Options	Logistic Module	LM Cargo	Payload Module
1012	----	----	----
150			
190			
672			
	[5821]	[8745]	[6409]
	(582)	(1571)	(641)
----	29	----	34
----	39	----	98
84	3	----	3
----	2	117	----
----	42	----	160
----	17	----	3
----	----	----	----
----	30	840	43
438	30	614	34
----	390	----	266
	[6403]	[10316]	[7050]
	(92)	(1271)	(227)
----	92	----	184
----	----	101	----
----	----	----	43
----	----	----	----
90	----	----	----
----	----	----	----
		1170	
	( )	(1458)	( )
		450	

		1008	
	[6495]	[13045]	[7277]

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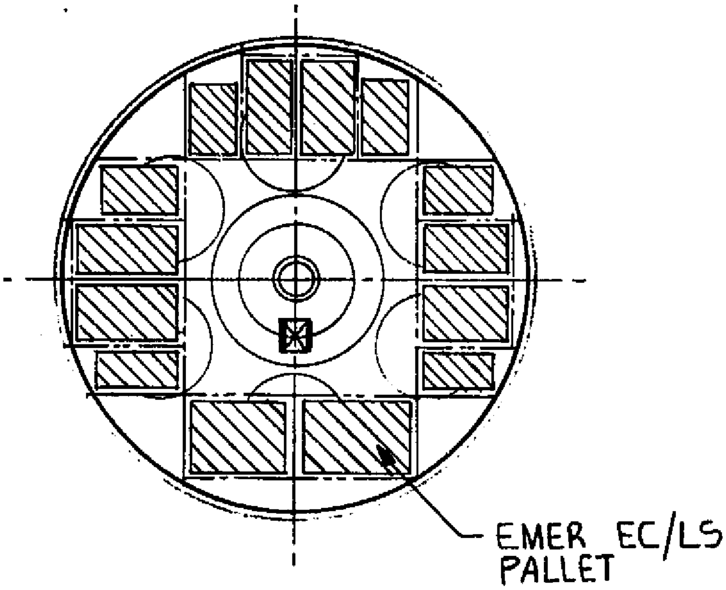

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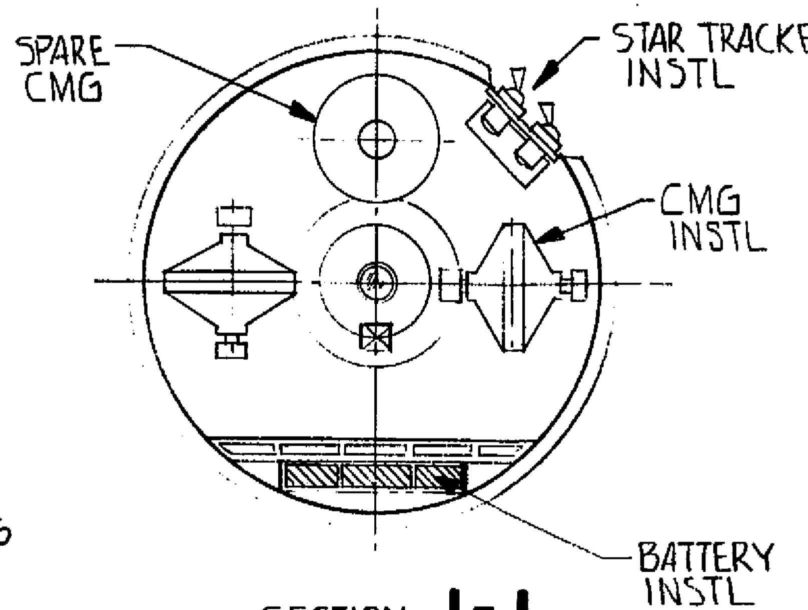

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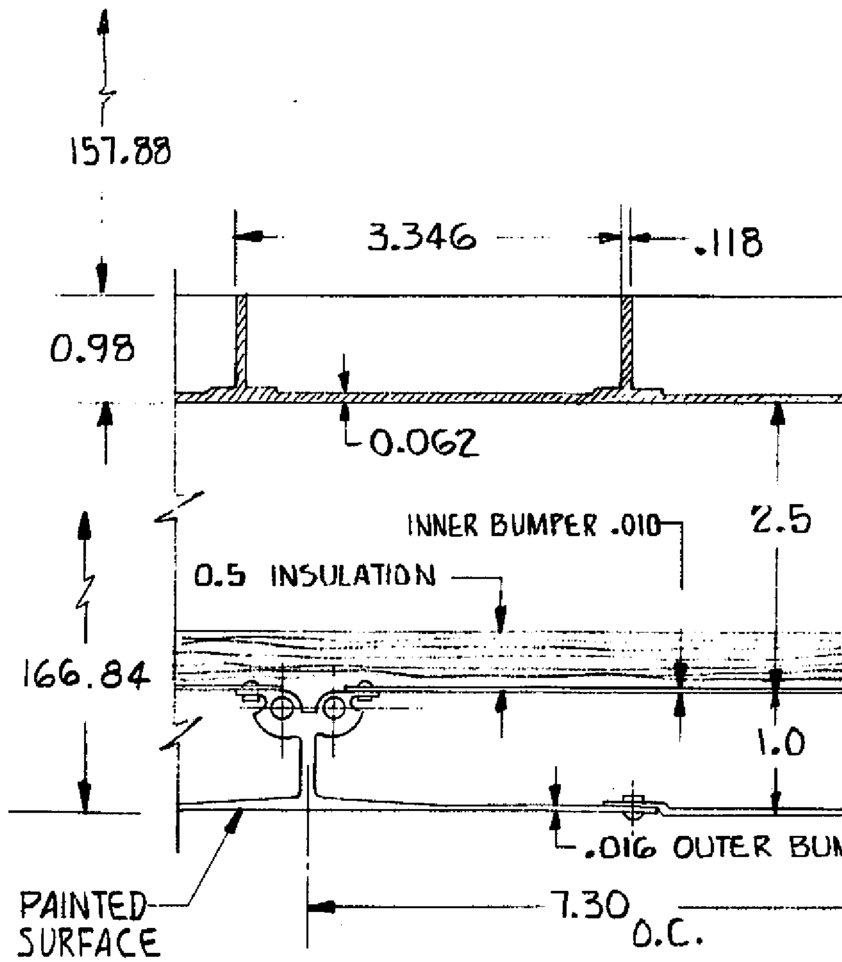

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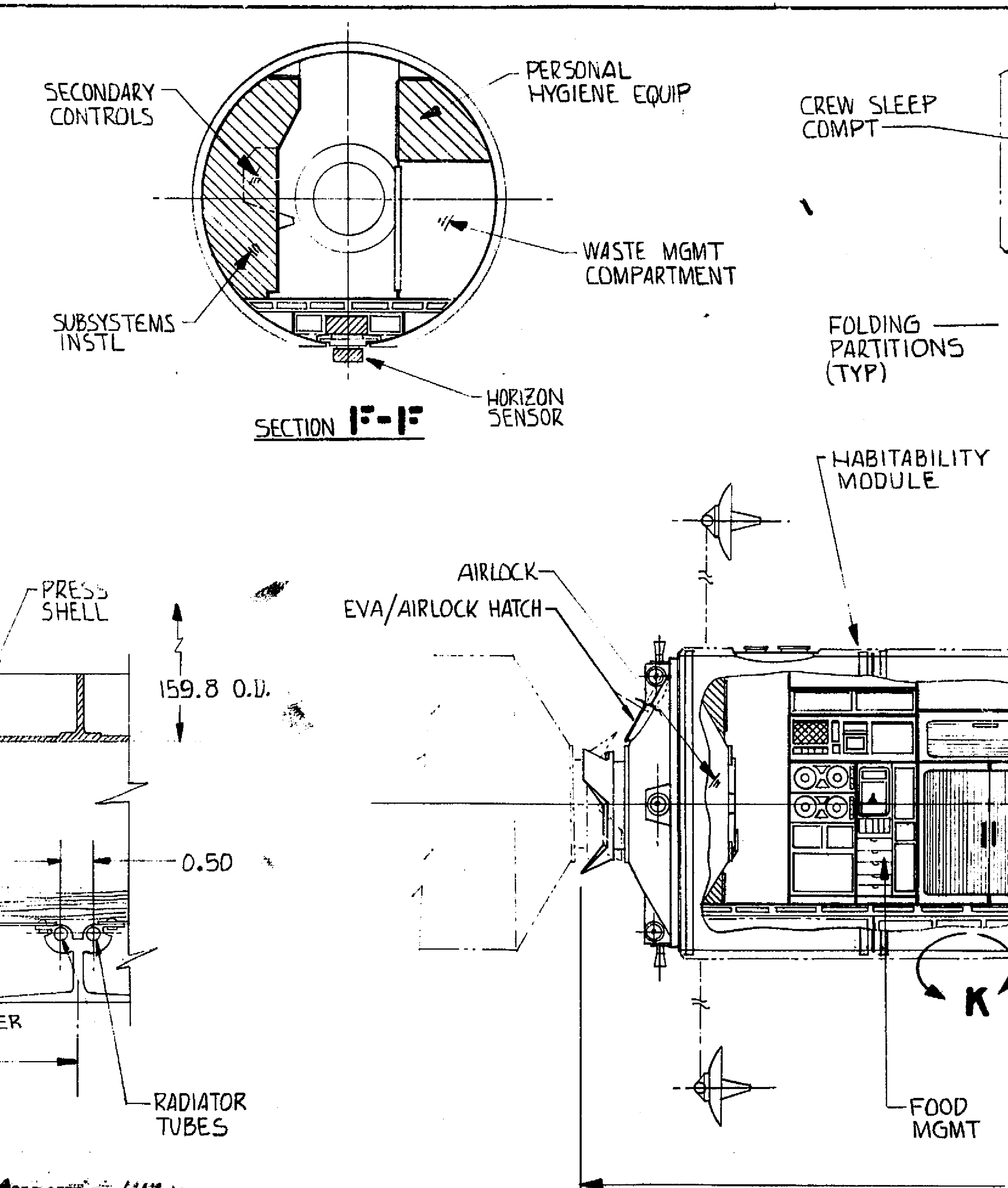

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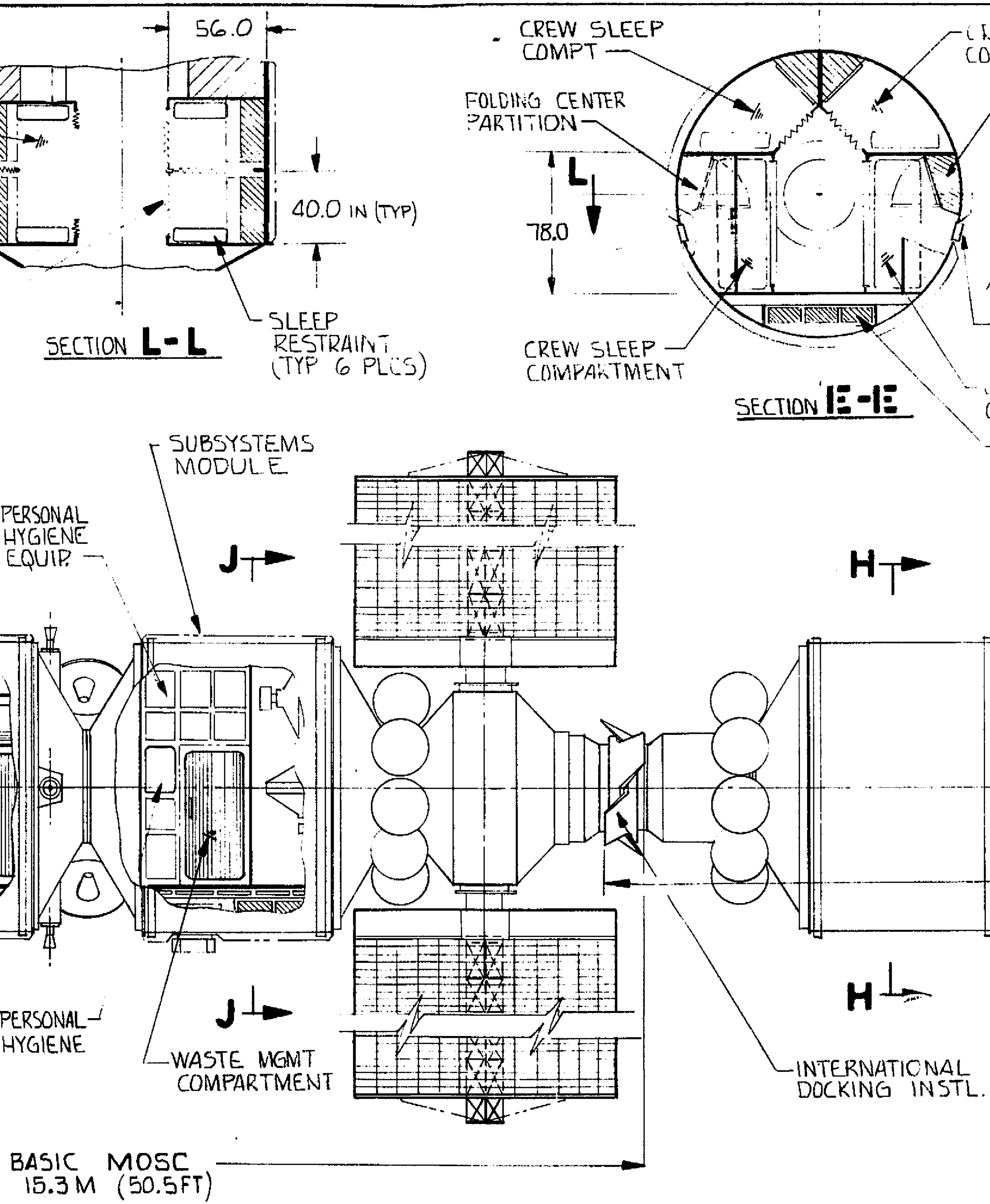

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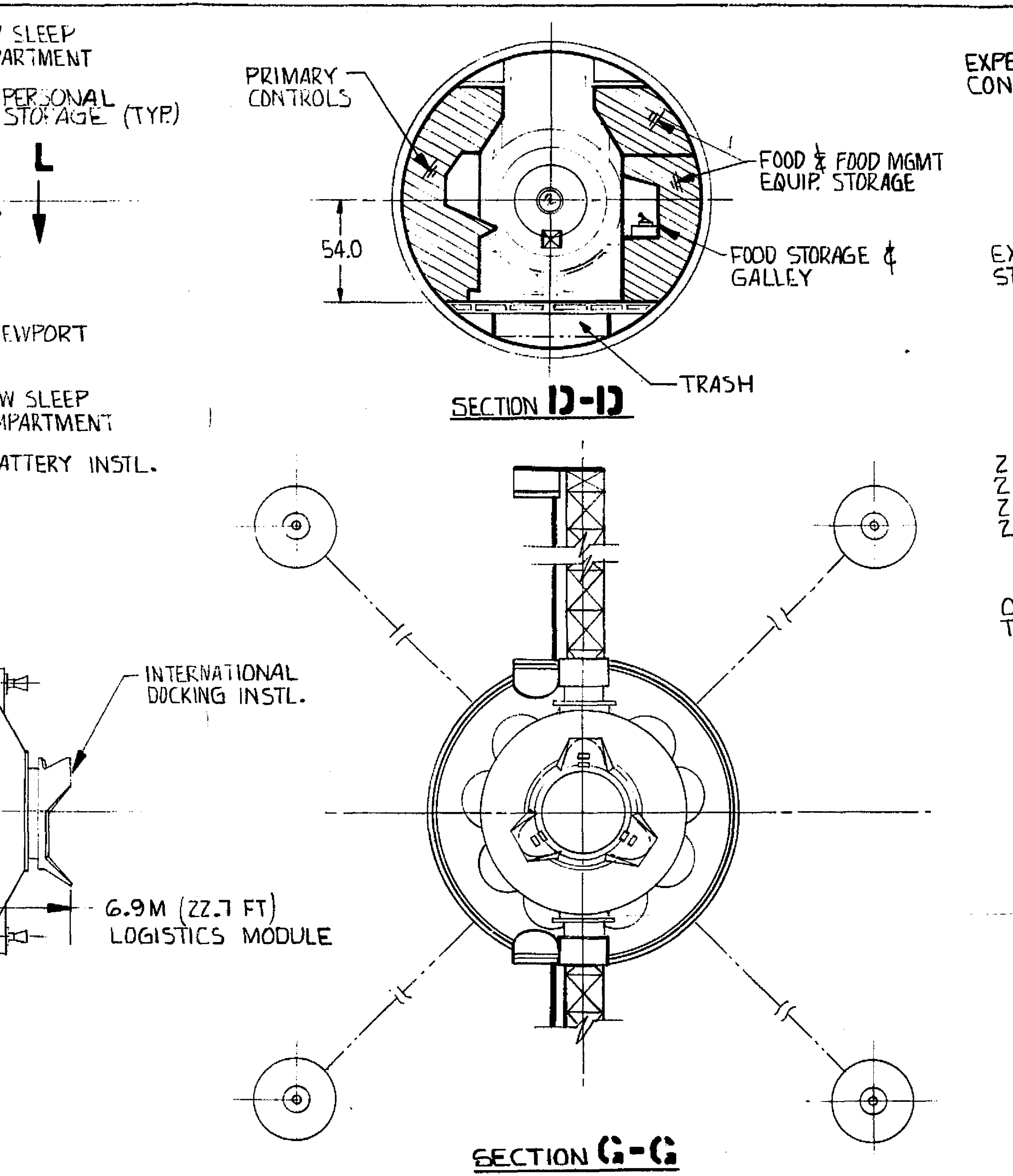

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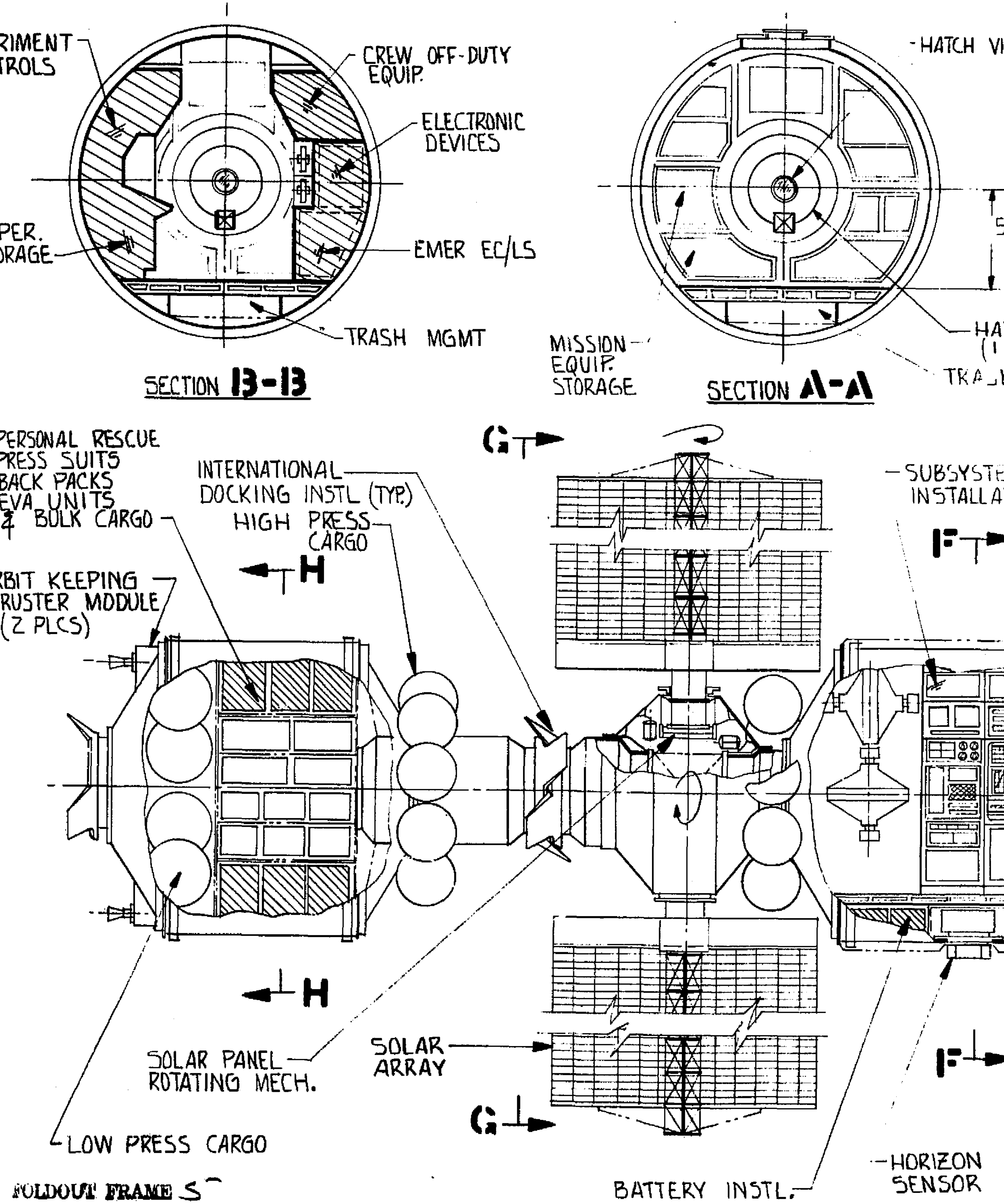

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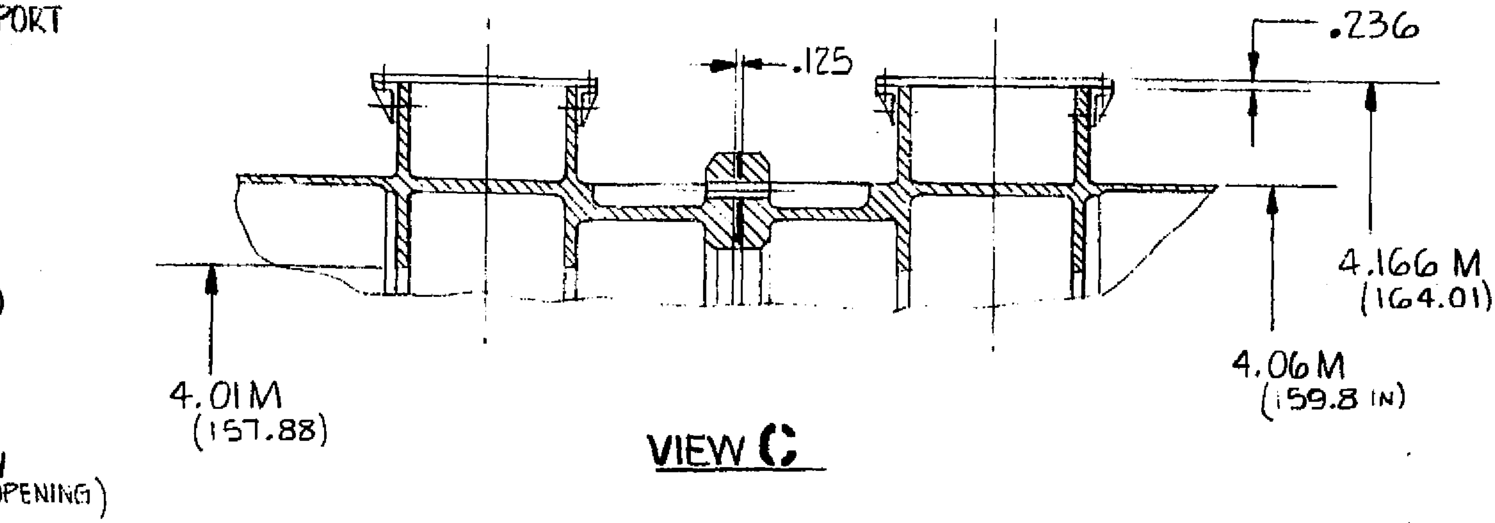

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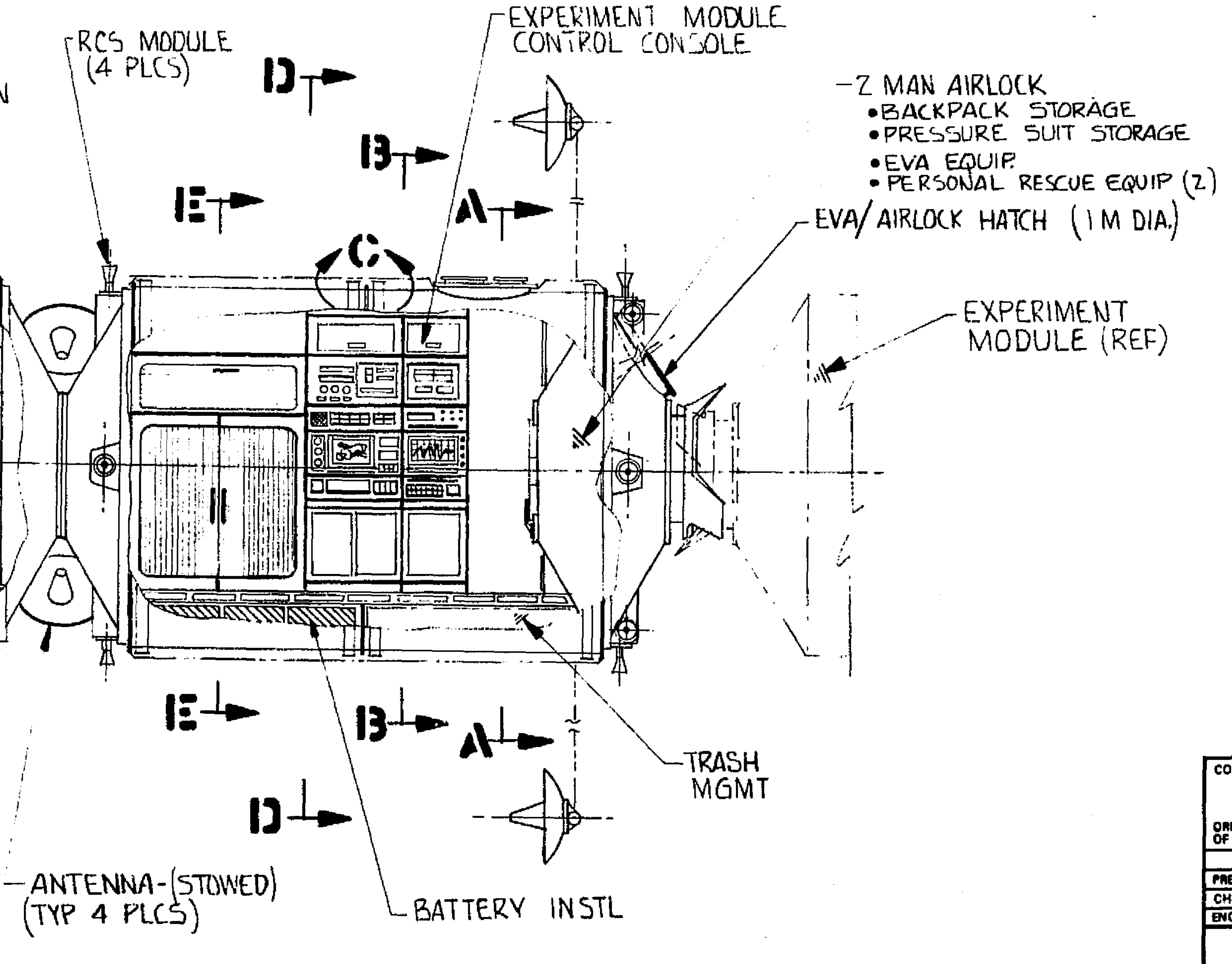

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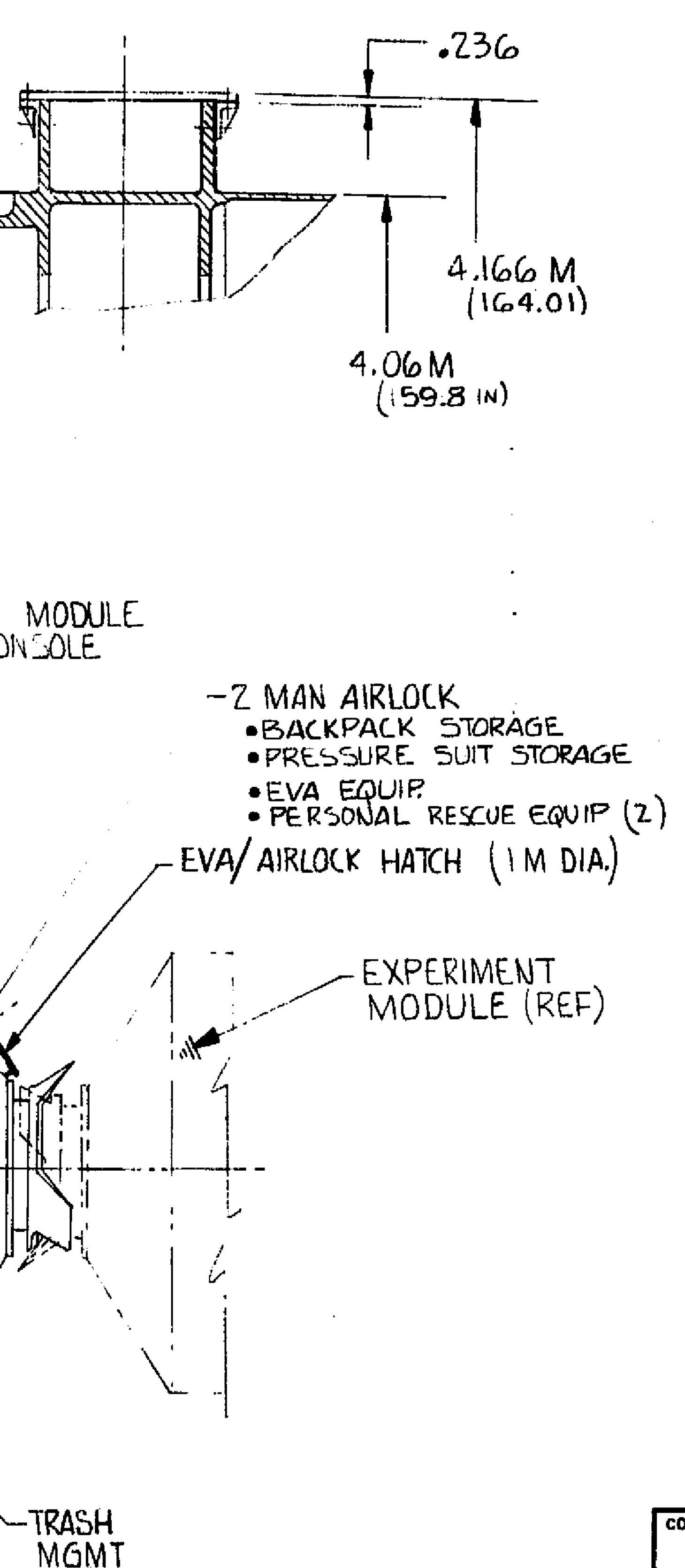

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CONTRACT NO.	MCDONNELL DOUGLAS ASTRONAUTICS CO. WESTERN DIVISION HUNTINGTON BEACH, CALIFORNIA
ORIGINAL DATE OF DRAWING	INBOARD PROFILE 6 MAN MOSC (GROWTH CONCEPT)
PREPARED G. KING 15 APR 75	
CHECKED [illegible] June 75	
ENGINEER [illegible]	
DESIGN ACTIVITY APPROVAL [signature]	SIZE; CODE IDENT NO. 18355; DRAWING NO. GK 041675
CUSTOMER APPROVAL	
	SCALE 1/40; SHEET 1 OF 1

Appendix G
COMPUTERIZED MASS PROPERTY LIMIT ANALYSIS

Appendix G
COMPUTERIZED MASS PROPERTY LIMIT ANALYSIS

In addition to the mass summaries of the Baseline MOSC configuration appearing in Section 5.1, an analysis of a typical configuration buildup was made, utilizing an MDAC H250 computer program. Nine steps or discrete points in time were examined and included the incremental addition of experiment modules, logistics modules and a 650 ft diameter (200 meter) 25,000 lb (11,340 kg) Radio Astronomy Telescope. These nine steps are as follows:

1. Habitability Module plus Subsystem Module (Launch 1)
2. Above plus Logistic Module (Launch 2)
3. Above (No. 2) plus Payload Module (Launch 2)
4. Above (No. 3) less Logistic Module
5. Above (No. 1) plus Telescope Mast
6. Above (No. 5) plus Logistic Module
7. Above (No. 6) plus Telescope Antenna
8. Above (No. 7) less Logistic Module
9. Radio Astronomy Telescope alone

The mass values on the following pages (Table G-1) are representative only and in some cases vary slightly from the final mass summaries of the individual modules as reported in Section 5. The intent of this analysis was to illustrate the conceptual feasibility of the design approach only.

Specific characteristics of the resulting cg's, moments of inertia, products of inertia and direction cosines can be expected to change slightly as more detailed design information becomes available.

In the following tables several points of clarification are necessary: the H250 computer program prints H for the longitudinal cg (X_o), V for the vertical (Z_o) and L for the lateral (Y_o). Figure G-1 references the coordinate axes

and reference station employed for these cases. In addition to the weight summaries, and resulting cg's, the moments of inertia, products of inertia, direction cosines, and principal angles are included. Again, the reader is cautioned that these values are preliminary as this was a top-down approach to investigate total mass properties and each module was assumed to have a small centerline offset, as would be the case with actual hardware.

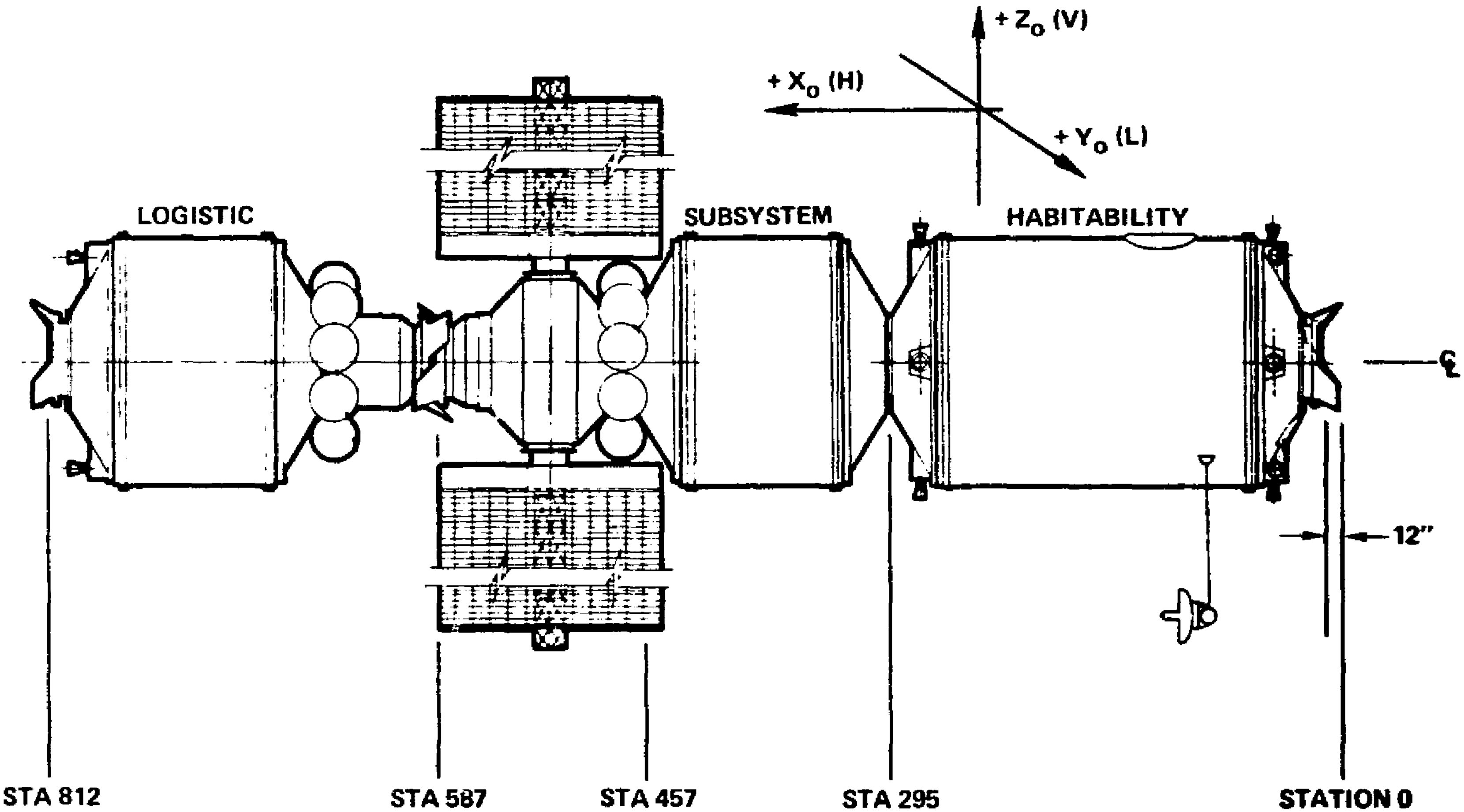

Figure G-1. MOSC Coordinate Axes and Reference Station

Table G-1

F253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM DESCRIPTION	WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
10. HAB MODULE	16060.00	165.00	-1.20	0.10	0.3221500E+08	0.1379100E+09	0.1479900E+09
20. TURRET	780.00	513.00	0.10	0.10	0.4800000E+07	0.2166400E+08	0.2166400E+08
30. SOLAR ARRAY	2375.00	513.00	0.10	0.10	0.1104000E+10	0.3980000E+07	0.3980000E+07
40. SER MODULE	14195.00	381.00	-0.00	0.10	0.3158300E+08	0.4977000E+08	0.5505100E+08
CONF. 1 TOTAL	33410.00	289.64	-0.57	0.10	0.1172610E+10	0.7387008E+09	0.7540742E+09
					SL-FT2	SL-FT2	SL-FT2
					0.2530963E+06	0.1594412E+06	0.1627594E+06

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MDSC GROWTH MASS PROPERTIES 4-12-75 PAGE A 1

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                         M253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION
                                      PRINCIPAL AXES DATA
                                       CONFIGURATION   1

WEIGHT                  33410.00 LBMASS
H-ARM                     289.64 INCHES
V-ARM                      -0.57 INCHES
L-ARM                       0.10 INCHES

ROLL MOI          0.1172610E+10 LB/IN2  0.2530963E+06 SL-FT2

YAW MOI           0.7387008E+09 LB/IN2  0.1594412E+06 SL-FT2

PITCH MOI         0.7540742E+09 LB/IN2  0.1627594E+06 SL-FT2

ROLL POI         -0.1455192E-10 LB/IN2 -0.3140886E-14 SL-FT2

YAW POI           0.7450581E-08 LB/IN2  0.1608134E-11 SL-FT2

PITCH POI         0.2472440E+07 LB/IN2  0.5336516E+03 SL-FT2


PRINCIPAL MOI 1   0.1172624E+10 LB/IN2  0.2530994E+06 SL-FT2

DIRECTION COSINES    COSH=  0.9999838E+00    COSV= -0.5697776E-02    COSL= -0.1780083E-16

PRINCIPAL ANGLES     FROM +H=  0.33 DEG    FROM +V= 90.33 DEG    FROM +L= 90.00 DEG

PRINCIPAL MOI 2   0.7386868E+09 LB/IN2  0.1594382E+06 SL-FT2

DIRECTION COSINES    COSH=  0.5697776E-02    COSV=  0.9999838E+00    COSL=  0.1813165E-17

PRINCIPAL ANGLES     FROM +H= 89.67 DEG    FROM +V=  0.33 DEG    FROM +L= 90.00 DEG

PRINCIPAL MOI 3   0.7540742E+09 LB/IN2  0.1627594E+06 SL-FT2

DIRECTION COSINES    COSH=  0.1779021E-16    COSV= -0.1914561E-17    COSL=  0.1000000E+01

PRINCIPAL ANGLES     FROM +H= 90.00 DEG    FROM +V= 90.00 DEG    FROM +L=  0.00 DEG

DESATURATION COEF. = 0.1073528E+01     (IPMAX+IPMID)/2 = 0.7633494E+09 LB/IN2,  0.2079294E+06 SL-FT2

MDSC GROWTH MASS PROPERTIES 4-12-75                                                   PAGE C  1
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Table G-1 (Continued) H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM DESCRIPTION	WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
10. HAB MODULE	16060.00	165.00	-1.20	0.10	0.3221500E+08	0.1379100E+09	0.1479900E+09
20. TURRET	780.00	513.00	0.10	0.10	0.4800000E+07	0.2166400E+08	0.2166400E+08
30. SOLAR ARRAY	2375.00	513.00	0.10	0.10	0.1104000E+10	0.3980000E+07	0.3980000E+07
40. SER MODULE	14193.00	361.00	-0.00	0.10	0.3158300E+08	0.4977000E+08	0.5505100E+08
50. LOGISTIC	17580.00	723.00	-1.00	-1.00	0.2194400E+08	0.2206600E+09	0.2367800E+09
CONF. 2 TOTAL	50990.00	439.05	-0.72	-0.28	0.1224170E+10	0.3122680E+10	0.3154161E+10
					SL-FT2	SL-FT2	SL-FT2
					0.2642250E+06	0.6739994E+06	0.6807944E+06

MOSC GROWTH MASS PROPERTIES 4-12-75 PAGE A 2

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Table G-1 (Continued)

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M253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION
                PRINCIPAL AXES DATA
                CONFIGURATION   2

WEIGHT             50990.00 LBMASS
H-ARM                439.05 INCHES
V-ARM                 -0.72 INCHES
L-ARM                 -0.28 INCHES

ROLL MOI        0.1224170E+10 LB/IN2   0.2642250E+06 SL-FT2

YAW MOI         0.3122680E+10 LB/IN2   0.6739994E+06 SL-FT2

PITCH MOI       0.3154161E+10 LB/IN2   0.6807944E+06 SL-FT2

ROLL POI        0.5481502E+04 LB/IN2   0.1183128E+01 SL-FT2

YAW POI        -0.5491047E+07 LB/IN2  -0.1185192E+04 SL-FT2

PITCH POI       0.3129034E+06 LB/IN2   0.6753708E+02 SL-FT2


PRINCIPAL MOI 1  0.3154177E+10 LB/IN2  0.6807978E+06 SL-FT2

DIRECTION COSINES    COSH=  0.2845124E-02    COSV= -0.2022948E-03    COSL=  0.9999959E+00

PRINCIPAL ANGLES     FROM +H= 89.84 DEG    FROM +V= 90.01 DEG    FROM +L=  0.16 DEG

PRINCIPAL MOI 2  0.1224155E+10 LB/IN2  0.2642217E+06 SL-FT2

DIRECTION COSINES    COSH=  0.9999959E+00    COSV=  0.1648051E-03    COSL= -0.2845091E-02

PRINCIPAL ANGLES     FROM +H=  0.16 DEG    FROM +V= 89.99 DEG    FROM +L= 90.16 DEG

PRINCIPAL MOI 3  0.3122680E+10 LB/IN2  0.6739994E+06 SL-FT2

DIRECTION COSINES    COSH= -0.1642286E-03    COSV=  1.0000000E+00    COSL=  0.2027629E-03

PRINCIPAL ANGLES     FROM +H= 90.01 DEG    FROM +V=  0.01 DEG    FROM +L= 89.99 DEG

DESATURATION COEF. = 0.1215320E+03     (IPMAX+IPMID)/2 = 0.3138428E+10 LB/IN2,  0.6773986E+06 SL-FT2

MOSC GROWTH MASS PROPERTIES 4-12-75                                                    PAGE C  2
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Table G-1 (Continued)

M253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM	DESCRIPTION	WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
10.	MAB MODULE	16060.00	165.00	-1.20	0.10	0.3221500E+08	0.1379100E+09	0.1479900E+09
20.	TURRET	780.00	513.00	0.10	0.10	0.4800000E+07	0.2166400E+08	0.2166400E+08
30.	SOLAR ARRAY	2375.00	513.00	0.10	0.10	0.1104000E+10	0.3980000E+07	0.3980000E+07
40.	SER MODULE	14195.00	381.00	-0.00	0.10	0.3158300E+08	0.4977000E+08	0.5505100E+08
50.	LOGISTIC	17580.00	723.00	-1.00	-1.00	0.5154400E+08	0.2206800E+09	0.2367600E+09
61.	EXP 3M	11420.00	-97.00	-1.00	1.00	0.5154400E+08	0.2777700E+07	0.2800000E+07
CONF. 3	TOTAL	62410.00	340.96	-0.77	-0.05	0.1275731E+10	0.5806517E+10	0.5838007E+10
						SL-FT2	SL-FT2	SL-FT2
						0.2753538E+06	0.1253279E+07	0.1260076E+07

Table G-1 (Continued)

```
                         H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION
                                        PRINCIPAL AXES DATA
                                         CONFIGURATION   3

    WEIGHT                  62410,00 LBMASS
    H-ARM                     340,96 INCHES
    V-ARM                      -0,77 INCHES
    L-ARM                      -0,05 INCHES

    ROLL MOI           0,1275731E+10 LB/IN2  0,2753538E+06 SL-FT2

    YAW MOI            0,5806517E+10 LB/IN2  0,1253279E+07 SL-FT2

    PITCH MOI          0,5838007E+10 LB/IN2  0,1260076E+07 SL-FT2

    ROLL PCI           0,2098201E+04 LB/IN2  0,4528758E+00 SL-FT2

    YAW POI           -0,1188924E+08 LB/IN2 -8,2566175E+04 SL-FT2

    PITCH POI          0,1730617E+07 LB/IN2  0,3735365E+03 SL-FT2


    PRINCIPAL MOI 1  0,5838038E+10 LB/IN2  0,1260082E+07 SL-FT2

    DIRECTION COSINES    COSH=  0,2606042E-02    COSV= -0,2096502E-03    COSL=  0,9999966E+00

    PRINCIPAL ANGLES     FROM +H= 89,85 DEG    FROM +V= 90,01 DEG    FROM +L=  0,15 DEG

    PRINCIPAL MOI 2  0,1275699E+10 LB/IN2  0,2753469E+06 SL-FT2

    DIRECTION COSINES    COSH=  0,9999965E+00    COSV=  0,3819631E-03    COSL= -0,2605962E-02

    PRINCIPAL ANGLES     FROM +H=  0,15 DEG    FROM +V= 89,98 DEG    FROM +L= 90,15 DEG

    PRINCIPAL MOI 3  0,5806518E+10 LB/IN2  0,1253279E+07 SL-FT2

    DIRECTION COSINES    COSH= -0,3614155E-03    COSV=  0,9999999E+00    COSL=  0,2106449E-03

    PRINCIPAL ANGLES     FROM +H= 90,02 DEG    FROM +V=  0,02 DEG    FROM +L= 89,99 DEG

    DESATURATION COEF. = 0,2884910E+03     (IPMAX+IPMID)/2 = 0,5822278E+10 LB/IN2.  0,1256681E+07 SL-FT2

    MOSC GROWTH MASS PROPERTIES 4-12-75                                                    PAGE C  3
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Table G-1 (Continued)

H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM	DESCRIPTION	WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
10.	HAB MODULE	16060.00	165.00	-1.20	0.10	0.3221500E+08	0.1379100E+09	0.1479900E+09
20.	TURRET	780.00	513.00	0.10	0.10	0.4800000E+07	0.2166400E+08	0.2166400E+08
30.	SOLAR ARRAY	2375.00	513.00	0.10	0.10	0.1104000E+10	0.3980000E+07	0.3980000E+07
40.	SER MODULE	14195.00	381.00	-0.00	0.10	0.3158300E+08	0.4977000E+08	0.5505100E+08
61.	EXP 3M	11420.00	-97.00	-1.00	1.00	0.3154400E+08	0.2777700E+07	0.2800000E+07
CONF. 4	TOTAL	44830.00	191.14	-0.68	0.33	0.1224163E+10	0.2013747E+10	0.2029138E+10
						SL-FT2	SL-FT2	SL-FT2
						0.2642234E+06	0.4346473E+06	0.4379692E+06

MOSC GROWTH MASS PROPERTIES 4-12-75

Table G-1 (Continued)

```
                 P253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION
                                  PRINCIPAL AXES DATA
                                   CONFIGURATION   4

WEIGHT                 44830,00 LBMASS
H-ARM                    191,14 INCHES
V-ARM                    -0,68 INCHES
L-ARM                     0,33 INCHES

ROLL MOI         0,1224163E+10 LB/IN2  0,2642234E+06 SL-FT2

YAW MOI          0,2013747E+10 LB/IN2  0,4346473E+06 SL-FT2

PITCH MOI        0,2029138E+10 LB/IN2  0,4379692E+06 SL-FT2

ROLL POI        -0,3313698E+04 LB/IN2 -0,7152288E+00 SL-FT2

YAW POI         -0,2961540E+07 LB/IN2 -0,6392191E+03 SL-FT2

PITCH POI        0,3895987E+07 LB/IN2  0,8409100E+03 SL-FT2


PRINCIPAL MOI 1  0,2029149E+10 LB/IN2  0,4379716E+06 SL-FT2

DIRECTION COSINES     COSH=  0,3682439E-02    COSV= -0,7163717E-03    COSL=  0.9999930E+00

PRINCIPAL ANGLES      FROM +H= 89,79 DEG    FROM +V= 90.04 DEG    FROM +L=  0,21 DEG

PRINCIPAL MOI 2  0,1224133E+10 LB/IN2  0,2642169E+06 SL-FT2

DIRECTION COSINES     COSH=  0,9999811E+00    COSV=  0,4933959E-02    COSL= -0,3678861E-02

PRINCIPAL ANGLES      FROM +H=  0,35 DEG    FROM +V= 89.72 DEG    FROM +L= 90,21 DEG

PRINCIPAL MOI 3  0,2013766E+10 LB/IN2  0,4346515E+06 SL-FT2

DIRECTION COSINES     COSH= -0,4931289E-02    COSV=  0,9999876E+00    COSL=  0,7345272E-03

PRINCIPAL ANGLES      FROM +H= 90,28 DEG    FROM +V=  0.29 DEG    FROM +L= 89,96 DEG

DESATURATION COEF, = 0,1036692E+03     (IPMAX+IPMID)/2 = 0,2021457E+10 LB/IN2,  0.4363115E+06 SL-FT2

MOSC GROWTH MASS PROPERTIES 4-12-75                                                       PAGE C  4
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H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM	DESCRIPTION	WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
10.	HAB MODULE	16060.00	165.00	-1.20	0.10	0.3221500E+08	0.1379100E+09	0.1479900E+09
20.	TURRET	780.00	513.00	0.10	0.10	0.4800000E+07	0.2166400E+08	0.2166400E+08
30.	SOLAR ARRAY	2375.00	513.00	0.10	0.10	0.1104000E+10	0.3980000E+07	0.3980000E+07
40.	SER MODULE	14195.00	381.[illegible]	-0.00	0.10	0.3158300E+08	0.4977000E+08	0.5505100E+08
62.	EXP ANT MAST	5000.00	-1200.00	0.00	0.00	0.5427000E+10	0.3768000E+10	0.3768000E+10
CONF. 7	TOTAL	38410.00	95.72	-0.49	0.09	0.6599612E+10	0.1415747E+11	0.1417285E+11
						SL-FT2	SL-FT2	SL-FT2
						0.1424461E+07	0.3055750E+07	0.3059068E+07

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MOSC GROWTH MASS PROPERTIES 4-12-75

Table G-1 (Continued)

M253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION
PRINCIPAL AXES DATA
CONFIGURATION 7

WEIGHT	38410.00 LBMASS	
H-ARM	95.72 INCHES	
V-ARM	-0.49 INCHES	
L-ARM	0.09 INCHES	
ROLL MOI	0.6599612E+10 LB/IN2	0.1424461E+07 SL-FT2
YAW MOI	0.1415747E+11 LB/IN2	0.3055750E+07 SL-FT2
PITCH MOI	0.1417285E+11 LB/IN2	0.3059068E+07 SL-FT2
ROLL POI	-0.2467652E+03 LB/IN2	-0.5326181E-01 SL-FT2
YAW POI	0.6478614E+06 LB/IN2	0.1398344E+03 SL-FT2
PITCH POI	-0.1203461E+07 LB/IN2	-0.2597550E+03 SL-FT2

PRINCIPAL MOI 1	0.1417285E+11 LB/IN2	0.3059068E+07 SL-FT2	
DIRECTION COSINES	COSH= -0.8554471E-04	COSV= 0.9353965E-05	COSL= 1.0000000E+00
PRINCIPAL ANGLES	FROM +H= 90.00 DEG	FROM +V= 90.00 DEG	FROM +L= 0.00 DEG
PRINCIPAL MOI 2	0.6599612E+10 LB/IN2	0.1424461E+07 SL-FT2	
DIRECTION COSINES	COSH= 1.0000000E+00	COSV= -0.1592330E-03	COSL= 0.8554619E-04
PRINCIPAL ANGLES	FROM +H= 0.01 DEG	FROM +V= 90.01 DEG	FROM +L= 90.00 DEG
PRINCIPAL MOI 3	0.1415747E+11 LB/IN2	0.3055750E+07 SL-FT2	
DIRECTION COSINES	COSH= 0.1592338E-03	COSV= 1.0000000E+00	COSL= -0.9340344E-05
PRINCIPAL ANGLES	FROM +H= 89.99 DEG	FROM +V= 0.01 DEG	FROM +L= 90.00 DEG

DESATURATION COEF. = 0.9841604E+03 (IPMAX+IPMID)/2 = 0.1416516E+11 LB/IN2, 0.3057409E+07 SL-FT2

MOSC GROWTH MASS PROPERTIES 4-12-75

Table G-1 (Continued)

H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM	DESCRIPTION	WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
10.	MAB MODULE	16060.00	165.00	-1.20	0.10	0.3221500E+08	0.1379100E+09	0.1479900E+09
20.	TURRET	785.00	513.00	0.10	0.10	0.4800000E+07	0.2166400E+08	0.2166400E+08
30.	SOLAR ARRAY	2375.00	513.00	0.10	0.10	0.1104000E+10	0.3980000E+07	0.3980000E+07
40.	SER MODULE	14195.00	381.00	-0.00	0.10	0.3158300E+08	0.4977000E+08	0.5505100E+08
50.	LOGISTIC	17580.00	723.00	-1.00	-1.00	0.5154400E+08	0.2206600E+09	0.2367800E+09
62.	EXP ANT MAST	5000.00	-1200.00	0.00	0.00	0.5427000E+10	0.3768000E+10	0.3768000E+10
CONF. 8	TOTAL	55990.00	292.68	-0.65	-0.25	0.6651173E+10	0.1912353E+11	0.1915502E+11
						SL-FT2	SL-FT2	SL-FT2
						0.1435590E+07	0.4127625E+07	0.4134420E+07

Table G-1 (Continued)

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                    H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION
                                   PRINCIPAL AXES DATA
                                   CONFIGURATION   8

WEIGHT                  55990.00 LBMASS
H-ARM                     292.68 INCHES
V-ARM                      -0.65 INCHES
L-ARM                      -0.25 INCHES

ROLL MOI          0.6651173E+10 LB/IN2  0.1435590E+07 SL-FT2

YAW MOI           0.1912353E+11 LB/IN2  0.4127625E+07 SL-FT2

PITCH MOI         0.1915502E+11 LB/IN2  0.4134420E+07 SL-FT2

ROLL POI          0.6392633E+04 LB/IN2  0.1379786E+01 SL-FT2

YAW POI          -0.7575225E+07 LB/IN2 -0.1635037E+04 SL-FT2

PITCH POI        -0.5034933E+07 LB/IN2 -0.1086740E+04 SL-FT2


PRINCIPAL MOI 1  0.1915502E+11 LB/IN2  0.4134421E+07 SL-FT2

DIRECTION COSINES     COSH=  0.6057885E-03    COSV= -0.1061518E-03    COSL=  0.9999998E+00

PRINCIPAL ANGLES      FROM +H= 89.97 DEG    FROM +V= 90.01 DEG    FROM +L=  0.04 DEG

PRINCIPAL MOI 2  0.6651167E+10 LB/IN2  0.1435588E+07 SL-FT2

DIRECTION COSINES     COSH=  0.9999997E+00    COSV= -0.4036872E-03    COSL= -0.6058313E-03

PRINCIPAL ANGLES      FROM +H=  0.04 DEG    FROM +V= 90.02 DEG    FROM +L= 90.03 DEG

PRINCIPAL MOI 3  0.1912354E+11 LB/IN2  0.4127626E+07 SL-FT2

DIRECTION COSINES     COSH=  0.4037515E-03    COSV=  0.9999999E+00    COSL=  0.1059072E-03

PRINCIPAL ANGLES      FROM +H= 89.98 DEG    FROM +V=  0.02 DEG    FROM +L= 89.99 DEG

DESATURATION COEF. = 0.7932446E+03     (IPMAX+IPMID)/2 = 0.1913928E+11 LB/IN2,  0.4131023E+07 SL-FT2

MOSC GROWTH MASS PROPERTIES 4-12-75                                                    PAGE C  8
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Table G-1 (Continued)

H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM DESCRIPTION		WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
10.	HAB MODULE	16060.00	165.00	-1.20	0.10	0.3221500E+08	0.1379100E+09	0.1479900E+09
20.	TURRET	780.00	513.00	0.10	0.10	0.4800000E+07	0.2166400E+08	0.2166400E+08
30.	SOLAR ARRAY	2375.00	513.00	0.10	0.10	0.1104000E+10	0.3980000E+07	0.3980000E+07
40.	SER MODULE	14195.00	381.00	-0.00	0.10	0.3158300E+08	0.4977000E+08	0.5505100E+08
50.	LOGISTIC	17580.00	723.00	-1.00	-1.00	0.5154400E+08	0.2206600E+09	0.2367800E+09
62.	EXP ANT MAST	5000.00	-1200.00	0.00	0.00	0.5427000E+10	0.3768000E+10	0.3768000E+10
63.	EXP 650F ANT	20000.00	-360.00	0.00	0.00	0.1273800E+12	0.2038100E+12	0.2038100E+12
CONF. 9	TOTAL	75990.00	120.90	-0.48	-0.19	0.1340312E+12	0.2292110E+12	0.2292425E+12
						SL-FT2	SL-FT2	SL-FT2
						0.2892930E+08	0.4947291E+08	0.4947971E+08

MOSC GROWTH MASS PROPERTIES 4-12-75

Table G-1 (Continued)

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                 P253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION
                              PRINCIPAL AXES DATA
                               CONFIGURATION   9

WEIGHT               79990.00 LBMASS
H-ARM                  120.90 INCHES
V-ARM                   -0.48 INCHES
L-ARM                   -0.19 INCHES

ROLL MOI          0.1340312E+12 LB/IN2  0.2892930E+08 SL-FT2

YAW MOI           0.2292110E+12 LB/IN2  0.4947291E+08 SL-FT2

PITCH MOI         0.2292425E+12 LB/IN2  0.4947971E+08 SL-FT2

ROLL POI          0.8838144E+04 LB/IN2  0.1907626E+01 SL-FT2

YAW POI          -0.1002120E+08 LB/IN2 -0.2162977E+04 SL-FT2

PITCH POI        -0.1131117E+08 LB/IN2 -0.2441404E+04 SL-FT2

PRINCIPAL MOI 1  0.2292425E+12 LB/IN2  0.4947971E+08 SL-FT2

DIRECTION COSINES     COSH=  0.1052234E-03    COSV= -0.2428691E-03    COSL=  1.0000000E+00

PRINCIPAL ANGLES      FROM +H= 89.99 DEG      FROM +V= 90.01 DEG      FROM +L=  0.02 DEG

PRINCIPAL MOI 2  0.1340312E+12 LB/IN2  0.2892930E+08 SL-FT2

DIRECTION COSINES     COSH=  1.0000000E+00    COSV= -0.1188401E-03    COSL= -0.1052522E-03

PRINCIPAL ANGLES      FROM +H=  0.01 DEG      FROM +V= 90.01 DEG      FROM +L= 90.01 DEG

PRINCIPAL MOI 3  0.2292110E+12 LB/IN2  0.4947291E+08 SL-FT2

DIRECTION COSINES     COSH=  0.1188656E-03    COSV=  1.0000000E+00    COSL=  0.2428560E-03

PRINCIPAL ANGLES      FROM +H= 89.99 DEG      FROM +V=  0.02 DEG      FROM +L= 89.99 DEG

DESATURATION COEF. = 0.6046342E+04     (IPMAX+IPMID)/2 = 0.2292267E+12 LB/IN2,  0.4947631E+08 SL-FT2

MOSC GROWTH MASS PROPERTIES 4-12-75                                                    PAGE C  7
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Table G-1 (Continued) H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM	DESCRIPTION	WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
10.	HAB MODULE	16060,00	165,00	-1,20	0,10	0,3221500E+08	0,1379100E+09	0.1479900E+09
20.	TURRET	780,00	513,00	0,10	0,10	0,4800000F+07	0,2166400E+08	0.2166400E+08
30.	SOLAR ARRAY	2375,00	513,00	0,10	0,10	0,1104000E+10	0,3980000E+07	0.3980000E+07
40.	SER MODULE	14195,00	381,00	-0,00	0,10	0,3158300F+08	0,4977000E+08	0.5505100E+08
62.	EXP ANT MAST	5000,00	-1200,00	0,00	0.00	0,5427000E+10	0,3768000E+10	0.3768000E+10
63.	EXP 65CF ANT	20000,00	-360,00	0,00	0.00	0,1273800E+12	0,2038100E+12	0.2038100E+12
CONF. 10	TOTAL	58410,00	-60,32	-0,32	0.06	0,1339796E+12	0,2206989E+12	0,2207143E+12
						SL-FT2	SL-FT2	SL-FT2
						0,2891817E+08	0,4763566E+08	0.4763898E+08

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Table G-1 (Continued)

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M253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION
                    PRINCIPAL AXES DATA
                    CONFIGURATION  10

WEIGHT              58410,00 LBMASS
H-ARM                 -60,32 INCHES
V-ARM                  -0,32 INCHES
L-ARM                   0,06 INCHES

ROLL MOI           0,1339796E+12 LB/IN2  0,2891817E+08 SL-FT2

YAW MOI            0,2206989E+12 LB/IN2  0,4763566E+08 SL-FT2

PITCH MOI          0,2207143E+12 LB/IN2  0,4763898E+08 SL-FT2

ROLL POI          -0,8113551E+03 LB/IN2 -0,1751229E+00 SL-FT2

YAW POI            0,1169200E+07 LB/IN2  0,2523602E+03 SL-FT2

PITCH POI         -0,[illegible]61484E+07 LB/IN2 -0,8982150E+03 SL-FT2

PRINCIPAL MOI 1  0,2207143E+12 LB/IN2  0,4763898E+08 SL-FT2

DIRECTION COSINES    COSH= -0,1347784E-04    COSV=  0,4911388E-04    COSL=  1,0000000E+00

PRINCIPAL ANGLES     FROM +H= 90,00 DEG    FROM +V= 90,00 DEG    FROM +L=  0,00 DEG

PRINCIPAL MOI 2  0,1339796E+12 LB/IN2  0,2891817E+08 SL-FT2

DIRECTION COSINES    COSH=  1,0000000E+00    COSV= -0,4798799E-04    COSL=  0,1348020E-04

PRINCIPAL ANGLES     FROM +H=  0,00 DEG    FROM +V= 90,00 DEG    FROM +L= 90,00 DEG

PRINCIPAL MOI 3  0,2206989E+12 LB/IN2  0,4763566E+08 SL-FT2

DIRECTION COSINES    COSH=  0,4798866E-04    COSV=  1,0000000E+00    COSL= -0,4911323E-04

PRINCIPAL ANGLES     FROM +H= 90,00 DEG    FROM +V=  0,00 DEG    FROM +L= 90,00 DEG

DESATURATION COEF. = 0,1127959E+05     (IPMAX+IPMID)/2 = 0,2207066E+12 LB/IN2,  0,4763732E+08 SL-FT2

MOSC GROWTH MASS PROPERTIES 4-12-75                                              PAGE C  8
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Table G-1 (Continued) H253 PROGRAM--VEHICLE MASS PROPERTIES DETERMINATION

ITEM DESCRIPTION	WEIGHT	H ARM	V ARM	L ARM	ROLL MOI	YAW MOI	PITCH MOI
62. EXP ANT MAST	5000.00	-1200.00	0.00	0.00	0.5427000E+10	0.3768000E+10	0.3768000E+10
63. EXP 650F ANT	20000.00	-360.00	0.00	0.00	0.1273800E+12	0.2038100E+12	0.2038100E+12
CONF. 12 TOTAL	25000.00	-528.00	0.00	0.00	0.1328070E+12	0.2104004E+12	0.2104004E+12
					SL-FT2	SL-FT2	SL-FT2
					0.2866507E+08	0.4541284E+08	0.4541284E+08